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Health and Social Care Delivery Research

Extended Research Article

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

Terry P Brown,[1] Lazaros Andronis,[2] Asmaa El-Banna,[2] Benjamin KH Leung,[3] Theodoros Arvanitis,[4] Charles Deakin,[5] Aloysius N Siriwardena,[6] John Long,[7] Gareth Clegg,[8] Steven Brooks,[9] Timothy CY Chan,[3] Steve Irving,[10] Louise Walker,[11] Craig Mortimer,[12] Sandra Igbodo[13] and Gavin D Perkins[1,2,14*]

[1]NIHR Applied Research Collaboration West Midlands, Warwick Clinical Trials Unit, Warwick Medical School, University of Warwick, Coventry, UK
[2]Warwick Clinical Trials Unit, Warwick Medical School, University of Warwick, Coventry, UK
[3]Department of Mechanical and Industrial Engineering, University of Toronto, Toronto, Canada
[4]Digital Health Technology, University of Birmingham, Birmingham, UK
[5]Southampton University Hospital, Southampton, UK
[6]Community and Health Research Unit, University of Lincoln, Lincoln, UK
[7]Patient and Public Involvement Representative, Warwick, UK
[8]Usher Institute, University of Edinburgh, Edinburgh, UK
[9]Department of Emergency Medicine, Queens University, Kingston, Ontario, Canada
[10]Association of Ambulance Chief Executives, London, UK
[11]Isle of Wight NHS Trust, Isle of Wight, UK
[12]South-East Coast Ambulance Service NHS Foundation Trust, Coxheath, UK
[13]North-West Ambulance Service NHS Trust, Bolton, UK
[14]University Hospitals Birmingham NHS Foundation Trust, Birmingham, UK

*Corresponding author g.d.perkins@warwick.ac.uk

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This article

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Abstract

Background: Ambulance services treat over 32,000 patients sustaining an out-of-hospital cardiac arrest annually, receiving over 90,000 calls. The definitive treatment for out-of-hospital cardiac arrest is defibrillation. Prompt treatment with an automated external defibrillator can improve survival significantly. However, their location in the community limits opportunity for their use. There is a requirement to identify the optimal location for an automated external defibrillator to improve out-of-hospital cardiac arrest coverage, to improve the chances of survival.

Methods: This was a secondary analysis of data collected by the Out-of-Hospital Cardiac Arrest Outcomes registry on historical out-of-hospital cardiac arrests, data held on the location of automated external defibrillators registered with ambulance services, and locations of points of interest.

Walking distance was calculated between out-of-hospital cardiac arrests, registered automated external defibrillators and points of interest designated as potential sites for an automated external defibrillator. An out-of-hospital cardiac arrest was deemed to be covered if it occurred within 500 m of a registered automated external defibrillator or points of interest.

For the optimisation analysis, mathematical models focused on the maximal covering location problem were adapted.

A de novo decision-analytic model was developed for the cost-effectiveness analysis and used as a vehicle for assessing the costs and benefits (in terms of quality-adjusted life-years) of deployment strategies.

A meeting of stakeholders was held to discuss and review the results of the study.

Results: Historical out-of-hospital cardiac arrests occurred in more deprived areas and automated external defibrillators were placed in more affluent areas. The median out-of-hospital cardiac arrest – automated external defibrillator distance was 638 m and 38.9% of out-of-hospital cardiac arrests occurred within 500 m of an automated external defibrillator.

If an automated external defibrillator was placed in all points of interests, the proportion of out-of-hospital cardiac arrests covered varied greatly. The greatest coverage was achieved with cash machines. Coverage loss, assuming an automated external defibrillator was not available outside working hours, varied between points of interest and was greatest for schools.

Dividing the country up into 1 km^2 grids and placing an automated external defibrillator in the centre increased coverage significantly to 78.8%.

The optimisation model showed that if automated external defibrillators were placed in each points-of-interest location out-of-hospital cardiac arrest coverage levels would improve above the current situation significantly, but it would not reach that of optimisation-based placement (based on grids). The coverage efficiency provided by the optimised grid points was unmatched by any points of interest in any region.

An economic evaluation determined that all alternative placements were associated with higher quality-adjusted life-years and costs compared to current placement, resulting in incremental cost-effectiveness ratios over £30,000 per additional quality-adjusted life-year. The most appealing strategy was automated external defibrillator placement in halls and community centres, resulting in an additional 0.007 quality-adjusted life-year (non-parametric 95% confidence interval 0.004 to 0.011), an additional expected cost of £223 (non-parametric 95% confidence interval £148 to £330) and an incremental cost-effectiveness ratio of £32,418 per quality-adjusted life-year.

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

Conclusions: We have developed a data-driven framework to support decisions about public-access automated external defibrillator locations, using optimisation and statistical models. Optimising automated external defibrillator locations can result in substantial improvement in coverage. Comparison between placement based on points of interest and current placement showed that the former improves coverage but is associated with higher costs and incremental cost-effectiveness ratio values over £30,000 per additional quality-adjusted life-year.

Study registration: This study is registered as researchregistry5121.

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List of abbreviations

AED	automated external defibrillator
AHA	American Heart Association
BHF	British Heart Foundation
CEAC	cost-effectiveness acceptability curve
CII	cost inflation index
COA	census output area
CP	current placement
CPC	cerebral performance category
CPR	cardiopulmonary resuscitation
DfE	Department for Education
EAC	equivalent annual cost
EEAS	East of England Ambulance Service NHS Trust
EMAS	East Midlands Ambulance Service NHS Trust
EMS	emergency medical service
ERC	European Resuscitation Council
EVPI	expected value of perfect information
FLM	flexible location model
GIS	geographical information system
ICER	incremental cost-effectiveness ratio
ILCOR	International Liaison Committee on Resuscitation
IMD	Index of Multiple Deprivation
IOWAS	Isle of Wight Ambulance Service
LAS	London Ambulance Service NHS Trust
LSOA	lower-level super output area
LYG	life-year gained
MCLP	maximal covering location problem
MESR	maximum expected survival rate
NEAS	North-East Ambulance Service NHS Foundation Trust
NICE	National Institute for Health and Care Excellence
NWAS	North-West Ambulance Service NHS Trust
OHCA	out-of-hospital cardiac arrest
OHCAO	Out-of-Hospital Cardiac Arrest Outcomes
ONS	Office for National Statistics
PAD	public-access defibrillation
PCB	postal collection box
POI	point of interest
PPI	patient and public involvement
PSA	probabilistic sensitivity analysis
QALY	quality-adjusted life-year
RCUK	Resuscitation Council United Kingdom
RoE	radius of effectiveness
ROSC	return of spontaneous circulation
RUC	rural/urban classification
SCAS	South Central Ambulance Service NHS Foundation Trust
SEC	socioeconomic classification
SECAmb	South-East Coast Ambulance Service NHS Foundation Trust
SWAST	South-Western Ambulance Service NHS Foundation Trust
SWM	spatially weighted model
TTD	time to defibrillation
TWM	temporally weighted model
VF	ventricular fibrillation
VIF	variance inflation factor
VT	ventricular tachycardia
WMAS	West Midlands Ambulance Service University NHS Foundation Trust
WP	work package
YAS	Yorkshire Ambulance Service NHS Trust

Plain language summary

Ambulance services of the NHS treat over 32,000 people whose heart suddenly stops pumping effectively, a condition known as cardiac arrest. Despite ambulance services' best efforts fewer than 1 in 10 survive. Electric shock treatment, known as defibrillation, is one of the most effective treatments, and if it is given within a few minutes of the heart stopping, over half the people treated survive. It is now possible for public to use an automatic machine (defibrillator) to safely give an electric shock to the heart before the emergency services arrive. For the public to make best use of these machines they need to be in the right places.

In this study, we attempted to work out the best places to put defibrillators in communities, making them more accessible to use. We showed that defibrillators currently are sited disproportionately in more affluent areas of the country, and not used despite being within an accessible distance from where a cardiac arrest occurs. We assessed that if a defibrillator was installed at various points of interest the number of cardiac arrests that were covered increased significantly. We then used a computer to model the best locations for new defibrillators and calculate the optimal number needed. Placement based on this model showed that, for a smaller number of defibrillators, a similar improvement in coverage could be achieved.

A health economic analysis that considered the cost of purchasing and installing defibrillators showed that installing additional defibrillators in specific points of interest improved coverage, but it was also more costly compared to current defibrillator placement.

This research showed that significant improvement in cardiac arrest coverage could be achieved if defibrillators were placed intelligently in public settings. We also created a system that uses data to decide where to place public-access defibrillators in the community.

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.

Funding

This award was funded by the National Institute for Health and Care Research (NIHR) Health and Social Care Delivery Research programme (NIHR award ref: NIHR127368) and is published in full in Health and Social Care Delivery Research; Vol. 13, No. 5. See the NIHR Funding and Awards website for further award information.

Chapter 1 Background

Out-of-hospital cardiac arrest epidemiology

An out-of-hospital cardiac arrest (OHCA) is a time-sensitive, life-threatening emergency. English NHS ambulance services receive calls to attend over 90,000 OHCA cases annually.[1,2] Resuscitation is attempted in around 32,000 of these cases. About 1 in 4 maintain a return of spontaneous circulation (ROSC) by the time of hospital handover and fewer than 1 in 10 survive to hospital discharge. The 58,000 OHCAs in which the respective services do not attempt resuscitation are declared 'recognition of life extinct' on scene following guidelines laid out by the Joint Royal Colleges Ambulance Service Liaison Committee.[3]

The 'chain of survival' describes the essential, time-sensitive interventions that must be optimised to enable an emergency care system to maximise the chance of survival following an OHCA[4] (*Figure 1*). However, a chain is only as strong as its weakest link. The first two links, early recognition and early cardiopulmonary resuscitation (CPR), can buy time for the OHCA victim but are not definitive treatments in themselves. The key and most effective treatment for an OHCA is defibrillation.

Ventricular fibrillation (VF) and ventricular tachycardia (VT) are the most common causes of sudden OHCAs, and their prompt treatment with a defibrillator, within 3–5 minutes of collapse, can lead to survival rates in excess of 50%.[6–9] As time passes, the effectiveness of defibrillation declines and the likelihood of survival decreases, as the heart rhythm eventually degenerates to asystole, which is largely unresponsive to treatment.[10] The quality of life of OHCA survivors in general is good,[11,12] while bystander defibrillation decreases the risk of brain damage and discharge to nursing home following hospital admission even further.[13] Any delay between collapse and treatment of an OHCA decreases the probability of survival significantly.[14] A greater proportion of OHCAs may have a shockable rhythm (VF or VT), as high as 76%, at the time of collapse.[7,15] However, by the time the rhythm is assessed, it may have deteriorated to asystole.[16,17]

Early shocks from an automated external defibrillator (AED) improve the likelihood an individual sustaining an OHCA survives significantly. However, public-access AEDs are rarely used during OHCA. Overall, in England, about 5% of OHCAs have an AED applied before emergency medical service (EMS) arrival.[1,18,19] Automated external defibrillators are more likely to be used in public settings compared with a private residential setting.[20,21] Ringh and his colleagues conceptualised the 'chain of public-access defibrillation', which identified points in a pathway between collapse and AED use where potential barriers exist.[22] One key point on the pathway, and a previously identified barrier,[23] is the availability of an AED. There are several factors that affect AED availability at the time of an OHCA. One key issue relates to the proximity of AEDs to OHCA events in the community and their accessibility.

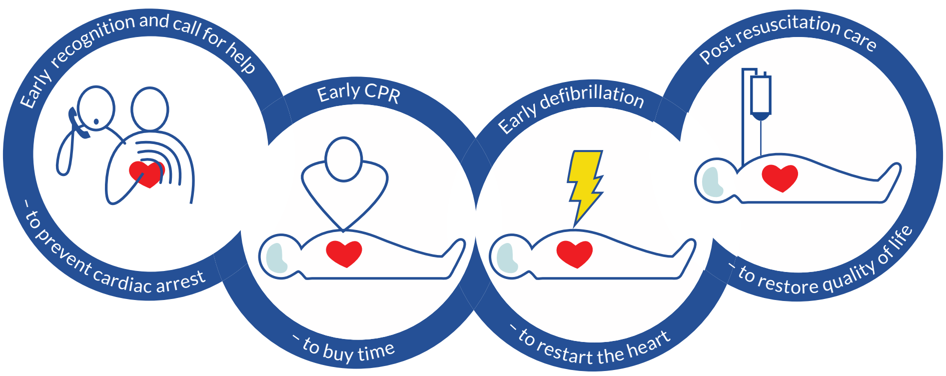

FIGURE 1 Chain of survival.[5]

Public-access defibrillation

Public-access defibrillation (PAD) describes the use of AEDs retrieved from fixed locations in the community by the public. Public-access defibrillation programmes allow the community access to this life-saving intervention while they wait for an ambulance to arrive. The aim of such programmes is to facilitate resuscitation and early defibrillation by a bystander. Early programmes involved the placement of AEDs in high-traffic public spaces, for example airports,[24,25] sporting grounds,[26] casinos,[9] and in places where EMS response is often delayed, for example aircrafts.[24,27]

The importance of PAD is growing given the increasing demands on ambulance services that make reaching an OHCA incident in a timely manner challenging. The latest data indicated the median response time was 7.4 minutes, with 47.5% of cases reached in 7 minutes, compared to 6.6 minutes and 53.8% in 2020.[1,2] However, at present, only a small proportion of UK patients are treated by PAD (2.4%),[19] with average time to use often exceeding 4 minutes,[6] leaving a large number of patients who fail to benefit from PAD. Intervention by the public, including using an AED, doubles the chance of survival with favourable neurological outcomes[28,29] and reduces hospital resource utilisation.[30–33]

A recent systematic review[23] identified and categorised barriers to successful PAD programmes, and systematic steps are being taken to address gaps in knowledge, education (e.g. major public training campaign in development), persuasion (e.g. updated PAD signage, ambulance dispatchers' prompts) and accessibility (e.g. national defibrillator database linked to ambulance services and responder apps, e.g. GoodSAM). However, a fundamental, structural barrier, which limits opportunity for the use of AEDs, is their location in the community. The further an OHCA victim is from an AED, the less likely it will be used, with the probability decreasing rapidly within the first 100 m from the OHCA location to the nearest accessible AED in public places, and the probability being low for all distances in residential areas.[34] Furthermore, the greater the distance to a defibrillator, the longer it takes to retrieve the device and the more time passes before defibrillation can be applied to the OHCA victim. This implies that survival and therefore the 'coverage' of an OHCA by a defibrillator decreases as a function of distance.[14,35–37] Each minute of delay of defibrillation reduces the probability of survival to discharge by 10%.[36] In the UK, there are improvements in survival of about 4% and 6% if the OHCA was witnessed by a bystander, or was bystander-witnessed and treated by CPR, respectively.[19] However, if a publicly accessible AED was also used survival rates almost quadrupled.

Nevertheless, AEDs are only cost-effective when located in places where the probability of their use is high, that is, they are not inside a building, are in an accessible cabinet, and are available 24 hours a day, 7 days a week.[33,38] There is a notably poor correlation reported between OHCA location and location of AEDs,[39,40] and 1 in 5 OHCAs occurred near an inaccessible AED at the time of the OHCA.[41] Also, in only a minority of OHCA cases (about 7%) was an AED located within 100 m.[42] Recent studies have also observed that significantly fewer AEDs were present in residential areas of urban settings and the median distance between OHCA location and the AED was larger there than in non-residential areas.[43] Similar observations are also seen in rural areas with low population densities, where long distances and geographical challenges make it difficult to reach OHCAs quickly. The retrieval distance for an AED has been correlated with the probability of death, the latter increasing by about 10% for every 100 m distance between an AED and the site of the OHCA, irrespective of the area's population density.[44]

There is sufficient evidence to recommend AED placement in specific locations wherever large numbers of people congregate, where there is a high OHCA risk, such as bus/railway stations, airports, convention centres, sports stadiums and arenas,[45–52] but not in other public sites. This would then provide legitimacy for funding and planning of public-access AED programmes. However, there is the question of where to locate AEDs in areas with a known high population density (residential and/or workday) and footfall that have been identified as OHCA 'hot spots'. These areas, for example postcode districts or super output areas (middle/lower layer), can cover vastly different areas, with variable design elements and geography. There are also other factors that need to be considered independently of population density, as recent research from the Out-of-Hospital Cardiac Arrest Outcomes (OHCAO) registry has shown.[53] These include the level of deprivation in the area, the proportion of people in the area from different ethnic minority groups and the proportion of people in different social classes. Rural areas also pose significant optimisation issues due to geographical challenges to cover villages; the distances between rural OHCAs and AEDs are significantly greater than in urban areas.[54] These longer retrieval distances have a significant impact on survival. For example, in densely populated areas in southern Denmark the average retrieval distance is about 105 m and 30-day survival 40%, compared to 350 m and 34% in thinly populated areas.[44]

Although millions of pounds are spent in the UK on the deployment of AEDs and training of individuals in their use, the impact is currently limited, given the reported extremely low utilisation rates during actual OHCAs.[19] Optimisation of the location of public-access AEDs will result in improved access to them, increase the proportion of OHCA victims who receive early defibrillation, and consequently result in an increased return on this societal investment.

Public-access defibrillation programmes that deploy AEDs are feasible, and their use by lay persons has proved an effective strategy in the management of OHCAs. A previous UK government-led scheme that placed AEDs in public places where OHCAs were known to occur most frequently showed that when an AED was used, a ROSC was achieved in 39% of patients and survival in 26%, and 47% and 31% when a shock was delivered,[55] compared to recent figures for England of 25.8% and 7%, respectively.[19] Despite several campaigns to raise public awareness and make PAD more available, many public areas have no recorded AED available.[56] Previously, the distribution of £1M of AEDs, funded by the Department of Health, and £2–3M from charities, was based on requests and allocated on a first-come, first-served, rather than strategic, basis.

Automated external defibrillator accessibility is also an important issue. In Denmark, one study reported that only 9% of installed AEDs are available at all hours of the day, and that limited AED accessibility during the evening, night-time and weekends, when about 62% of OHCAs in public locations occurred, decreased AED coverage by over 50%.[57] Recent work in the UK has shown that the availability of AEDs at night was only 34.3%, and existing AEDs were underused significantly – though 36.4% of OHCAs were located within 500 m of an AED.[54] The study also showed that about 6% of OHCAs were within a retrieval (walking) radius of 100 m during the day, falling to about 1.6% out of hours. Thus, not only strategic placement but also uninterrupted AED accessibility warrant attention if PAD is to improve chances of survival after an OHCA.

There is much debate about where AEDs should be placed, and whether there should be widespread dissemination of AEDs versus restricted placement at sites considered to be high-risk venues for OHCA. Deploying more AEDs for the sake of raw coverage may be a solution, but simply increasing the number of AEDs is not viable, as the placement of large numbers may be very costly if not managed properly and preceded by public awareness.[50,58–61] Instead, targeting AED placement matched to known country- and region-specific OHCA event rates, in addition to efforts to improve accessibility of existing AED units, is likely to be most cost-effective.[15,62–65] Furthermore, different approaches may be needed for public-versus-private coverage and metropolitan-versus-rural coverage.

Guidelines from the European Resuscitation Council (ERC) and the American Heart Association (AHA) suggest that decision-makers should consider the anticipated frequency of OHCAs (based on historical incidence evidence as outlined above; at least one OHCA every 5 years per 100 m^2) and the time to defibrillation (TTD) following collapse (3–5 minutes).[16,38,66,67] Anticipated OHCA frequency is based on evidence from North America that indicated OHCAs are more likely to occur in neighbourhoods with certain characteristics,[68–70] and analysis of data from the OHCAO registry.[53] This evidence is continually being updated in the UK as part of the work programme of the UK OHCAO registry, and any changes in pattern will inform any potential changes in guidelines and advice.

The strategies for the deployment of AEDs in public places in the UK remain somewhat arbitrary. The method of identifying these OHCA 'hot spots' to optimise AED deployment, and hence the location of a publicly accessible AEDs, in any given community is not clear, although a significant amount of work has been carried out in other countries.[41,51,71–73] Recently, data from the OHCAO registry have been used to identify the characteristics of neighbourhoods where OHCA incidence is high, as indicated earlier.[53] These neighbourhoods were also classified as 'high risk', where despite a high OHCA incidence the bystander CPR rate was low.

Historically, there has been no coordinated effort to identify locations where an AED should be placed. An early study in Denmark showed that when AEDs were placed by local or political initiatives none were used, and that they were primarily placed in low-incidence areas.[50] In England, AEDs have traditionally been placed in a very haphazard manner, with decisions being made by owners of the AED without consultation, and not coordinated centrally within a community. Perhaps it is reasonable to believe that the initiator of an AED being installed in a local community would choose the location based on media coverage and corporate social responsibility rather than likelihood of use. It has recently been shown that the more affluent areas of England that have a low OHCA incidence tended to be those served by an AED.[74] By contrast, the more deprived areas that are associated with a high incidence of OHCA[53] are those where a publicly accessible AED is lacking.

Survival benefits of public-access defibrillation schemes

Various organisations promote the placement of AEDs outdoors in public places so that they are always available, but, despite several UK campaigns to raise public awareness and make PAD more available, many public areas have no AED.[56,75] There has been no clear strategy in the UK on where AEDs should be placed; the choice of where to install AEDs 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.[50,76] There is a requirement to identify the optimal location for an AED to improve the coverage of OHCAs, in order to improve the chances of survival. If resources do allow deploying AEDs in all high-risk regions, the challenge remains to identify specific locations for AED placement within those regions. Also, outside those high-risk regions, there is no guidance to place AEDs at sites that are considered to possess a lower OHCA risk. Therefore, it is important to determine a relevant subset of locations for AED placement that have maximum impact on OHCA coverage. A prescriptive method for explicit and accurate AED deployment would be most useful. If, however, AED placement is driven by local and/or political initiatives, there is a risk of paradoxical AED placement in the community, with placement being primarily in affluent areas with low OHCA incidence.[50,51] This risks increasing health inequalities. Automated external defibrillator deployment strategies must switch from being subjective and opinion-based to being objective and evidence-based criteria. This will make it possible to identify the optimal number of, and best location for, outdoor AEDs.

The International Liaison Committee on Resuscitation (ILCOR) Consensus on Science with Treatment Recommendations carried out a systematic review of public-access AED programmes, noting that all outcomes improved significantly with the introduction of such a programme.[77] With varying degrees of evidence, they observed an increase in (1) survival to hospital discharge, 30 days and 1 year, with favourable neurological outcome; (2) survival to hospital discharge and 30 days, with unknown neurological outcome; (3) survival to hospital admission; and (4) ROSC. A further study from Japan, not included in the review, where public-access AEDs are well disseminated and numbers have increased significantly, showed that the programme led to early effective treatment of OHCAs of medical origin that occurred in public locations, with improving outcomes.[78]

Optimisation of automated external defibrillation deployment

There have been several studies that have looked at various approaches to optimise AED deployment, using geographic location of historical OHCAs to guide placement. These include density mapping, grid-based systems and landmark-based approaches, and optimisation models.

Density mapping

A general approach is to analyse the spatial distribution of historical OHCAs and then identify 'hot spots' that is, high-risk areas where the incidence is high. In the ERC guidelines, it is suggested that AEDs to be placed in densely populated areas, but no recommendations are given on the level of density.[16] Moon *et al.*[39] mapped OHCAs that occurred in metropolitan Phoenix, Arizona, using kernel density estimation, and overlapped the locations of AEDs. They found a weak correlation between OHCA events and deployed AEDs. However, they did identify areas where OHCAs occurred frequently but AEDs were lacking.

In Singapore, Zakaria and colleagues[79] identified categories and individual sites that fulfilled the AHA criteria of at least one OHCA per site every 5 years where a PAD programme could be focused and possibly prove cost-effective in saving lives. The locations category with the highest incidence [5.24 OHCAs per 5 years, 95% confidence interval (CI) 3.66 to 7.20] were port/airport/immigration checkpoints. The top individual site was Changi Airport, where the incidence was 25.0 OHCAs per 5 years (95% CI 16.18 to 36.90). They observed that 71% of OHCAs occurred in residential areas and identified several districts where the incidence was greater than 1 OHCA per 5 years.

In the Swiss canton of Vaud, Aeby *et al.*[80] assessed AED positioning in relation to locations of historical OHCAs, in order to improve the efficiency of PAD programmes. The distances between historical OHCAs and AEDs were calculated, as well as the number and rates of OHCAs covered (< 100 m). They identified areas with high densities of uncovered OHCAs (hot spots) to propose placement of additional AEDs and areas over-covered by AEDs to propose relocation of overlapping AEDs. Coverage was estimated at 7.5%, with OHCAs that occurred at home faring worse at 4.5%. Forty hot spots were identified where if an AED was placed it would result in an increased coverage to 17.6%. They also observed that relocating 17 existing AEDs would not reduce coverage.

However, although these methods can identify areas for AED placement, deciding where to place them within these high-risk areas is an additional task.

Grid-based approach

In Paris, a grid-based strategy with a regular distance between AEDs was considered and it was found that the number of AEDs and their distance to the nearest OHCA would change with the grid size.[73] They tested distances ranging from 200 to 2000 m. The optimal number of AEDs was between 200 and 400, which was reflected in a median distance to an OHCA of between 110 m [interquartile range (IQR) 70–144 m] and 226 m (IQR 168–284 m).

In Milan, Gianquintieri and colleagues[81] divided the city into 200 by 200 m (0.04 km^2) cells and looked at the OHCA incidence and AED numbers within them. They developed a geographic risk function for the estimation of OHCA occurrence probability. The optimisation method described was able to provide highly valuable decision-making support for policy-makers, from which new installations or re-displacement of existing AEDs could result in effective improvement in the spatial accessibility of publicly accessible AEDs. The proposed strategy for AED deployment resulted in significant increased coverage in OHCA spatial coverage (41.8–73.3%).

In Kaohsiung City, Taiwan, researchers identified the highest gaps between demand (OHCA cases) and supply (AED locations and EMS stations) for allocating AEDs based on an evaluation of spatial accessibility evaluation and priority-ranking.[82] They divided the city into basic area statistical centroids. A Bayesian spatial analysis with an integrated nested Laplace approximation method was applied to estimate the composite spatial risks from multiple factors, including population density, proportion of elderly people (> 65 years) and land use classification. The multi-criterion two-step floating catchment area method was used to measure the spatial accessibility of AEDs. They found that supply of AEDs was less than demand in most areas, especially rural areas, and identified priority places under limited resources for deploying AEDs based on transportation time to the nearest hospital and population size of the communities. They concluded that optimised deployment of AEDs can broaden EMS coverage and minimise the problems of the disparity in urban areas and the deficiency in rural areas.

Landmark approach

Various studies have evaluated OHCA risk according to location type.[9,45,46,49–51,83–85]

A study in Toronto identified that the top five location categories by average annual OHCAs per site were racetrack/casino (0.67), jail (0.62), hotel/motel (0.1), hostel/shelter (0.14) and convention centre (0.11).[51] Schools, where there was a low OHCA risk, represented 72.5% of AED-covered locations. Some high-risk locations were underrepresented with respect to AED coverage.

In Pittsburgh, it was hypothesised that if postal collection boxes (PCBs) were used to locate AEDs, coverage would increase overall, especially in residential areas, thus reducing the distance needed to travel from an OHCA to an AED.[86] Straight-line distance was calculated, assuming a ¼-mile (~ 400 m) radius around each existing AED augmented with PCB-AEDs. Coverage in the city overall increased to 55% (vs. 30% existing AEDs), in residential areas to 62% (vs. 27%) and in non-residential areas to 45% (vs. 30%). In this situation, the median distance was reduced significantly to 0.12 mile (~ 193 m) from 0.32 mile (~ 515 m). However, the cost of placing an AED at 479 PCBs was not explored.

In England, walking distance between 22,382 OHCAs that occurred in the region served by the South Central Ambulance Service NHS Foundation Trust (SCAS) between 2014 and 2018 and 52 common building types (24,155 buildings) was examined.[87] Post boxes were ranked first in both urban and rural areas, covering 11.7% of OHCAs at

100 m and 85.6% at 500 m. This finding was not surprising considering the number of post boxes in the region. In urban areas, bus shelters and telephone boxes also provided good coverage (9.7%, 9.5% at 100 m; 69.2%, 71.9% at 500 m), but again there were large numbers in the region. In rural areas the coverage provided by nursing/care homes and pubs/bars was also high (4.9%, 4.6% at 100 m; 15.2%, 31.8% at 500 m). When combinations of the building types were considered, coverage increased significantly to 89.0% for post boxes/phone boxes and 90.9% for post boxes/phone boxes/bus stops, at 500 m.

A systematic review of 16 studies observed that 35.2% of people receiving AEDs within 5 minutes survived, compared to 36.6% of those who received one between 5 and 10 minutes, and 28.4% for longer than 10 minutes.[88] Survival rates were 37.1% for those AEDs sited within 100 m of an OHCA, 22.0% within 100–200 m and 12.8% for > 200 m. Events that occurred in schools, sports venues and airports had significantly greater survival rates compared to other sites (39.3% vs. 23.5%). Survival rate improved with increased accessibility of AEDs in an area which could be measured by the density, distance to and time of access to AEDs.

A study in Perth, Australia, investigated where 10,422 non-traumatic OHCAs occurred in relation to 115 business brands (5006 facilities),[21] and their potential to supplement the coverage of existing registered AEDs. After accounting for AED-access hours, registered AEDs covered 23% of public location OHCAs (≤ 100 m) and 4% of private residences. Ten businesses increased coverage of public OHCAs, six of which also increased coverage for private residences. Public phone booths stood out clearly as highest-ranked of all brands, with more than double coverage compared to the next ranked. If all 115 business brands hosted an AED (24/7 access), 57% of OHCAs would remain without 100 m coverage for public OHCAs, and 92% in private residences. Many of the businesses ranking highly for coverage in public locations also ranked highly for OHCAs that occurred in private residences.

Work in British Columbia examined OHCAs in 10 urban communities, evaluating the potential 'radius of effectiveness' (RoE) of AED placement in all schools and/or community centres.[89] In the analysis it was assumed that all OHCAs had two available bystanders (one to initiate CPR, one to get AED), a round-trip bystander would take 4 minutes to retrieve an AED (factoring in standard walking and driving speeds), and an estimated 25% of those treated with an AED would survive. They estimated a RoE of 625 m for cars and 240 m for pedestrian retrievals. Within 10 urban communities 65% of all OHCAs fell within a vehicle's RoE, with only 15% within walking range, and it was determined that this placement strategy would be cost-effective based on previous work indicating a 12.5% probability cut-off of each device being used yearly.[90] An editorial stated that the Liang data[89] could serve as a solid foundation for a pre-hospital OHCA public health initiative, and that simply deploying AEDs in the community without an integrated pre-hospital response was unlikely to translate into a cost-effective practice that would improve OHCA survival.[91] The editorial stressed that in addition to strategic AED placement, governments could regulate the registration and location of all AEDs and maintain a geo-mapped registry of all locations. Public policy could be amended to require schools and community centres to provide, regularly monitor and service AEDs in a publicly available location 24/7.

Work in France has shown that the rate of AED use is extremely low, not exceeding 2% in Paris and its suburbs,[92] and 4% in France as a whole.[93,94] AED density varied throughout France from 5 to 3399 per 100,000 people per 1000 km^2, with density significantly correlated with survival. A study of Paris looked at the potential of deploying AEDs at five landmarks in the city: district council offices (n = 20), post offices (n = 195), subway stations (n = 302), bike-sharing stations (n = 957) and pharmacies (n = 1466).[73] The study observed that the median distance between these landmarks and OHCAs was 1052, 324, 239, 137 and 142 m, respectively. This landmark-based strategy resulted in the shortest OHCA-to-AED distances for the same total number of AEDs deployed (compared to a grid-based strategy). Placing AEDs at bike-sharing stations was the most cost-effective option.

In Toronto, OHCA coverage was assessed assuming an AED was placed in 41 business and municipal location types, with 20 or more locations in the city (4949 in total).[72] They calculated assumed coverage where an OHCA occurred within 100 m of any facility at any time of the day/week, and actual coverage if the OHCA occurred within 100 m of any facility when that facility was known to be open. Coverage loss was then calculated as: (assumed-actual)/assumed, and coverage efficiency as actual coverage/number of facilities. Coffee shops and banks occupied 8/10 top spots for OHCA coverage. The rankings exhibited a high temporal stability, both in the city centre and downtown.

Tsai and colleagues[95] used two models to consider the spatial and temporal characteristics of convenience stores and cardiac arrest in Taipei City (Taiwan) and used a genetic algorithm to solve the AED location problem. They considered installing an AED in every store belonging to a well-known chain, considering a service range of 100 m (human running) and 300 m (vehicle transportation), and applied two models, a temporally weighted (TWM) one and a spatially weighted (SWM) one. The TWM covered 54.8% of OHCAs if they occurred within 100 m of stores, whereas the SWM covered 46.4%. Figures for OHCAs within 300 m of the stores were 51.9% with the TWM and 41.1% with the SWM. The TWM selected more stores in commercial areas whereas the SWM selected more in residential areas. In commercial areas, the stores compensated for the temporal gap of EMS in night-time occurrences and for high OHCA incidence, whereas in residential areas, stores compensated for the spatial gap in areas far from EMS stations. Further analysis of the data confirmed these findings.[96]

In a systematic review of deployment strategies of AEDs, Liu and co-workers carried out a qualitative analysis of the utility and OHCA coverage of AEDs.[97] They demonstrated that a guidelines-based deployment was a common fit for OHCA events. Studies that used a grid-based strategy showed a threefold increase in the use of bystander defibrillation, with a doubling of 30-day survival. In studies that looked at a landmark-based strategy, offices, schools and sports facilities were the top three. However, they could not identify the optimal method to use.

These studies suggest that ranking locations on their risk of OHCA is an appropriate method to guide the placement of AEDs. However, there are several limitations to this approach. First, identification of high-risk locations is highly dependent on the demographics and infrastructure of the studied cities and therefore not generalisable. Second, a substantial number of OHCAs happen outdoors and cannot be categorised under any building type. Lastly, a high-risk building type may have many constituent facilities spread across the city, making broad AED deployment in this building type cost-prohibitive.

Optimisation approach

In the optimisation approach, the maximal covering location problem (MCLP) method has been the basis of the development of optimisation models for AED deployment. The MCLP aims to select the location of a fixed number of facilities to maximise covered nodes (OHCA location). A covered node has at least one facility within a predetermined distance or time. MCLP is designed to maximise the total amount of demand serviced (OHCAs) using a predetermined number of facilities (AEDs available 24/7). To be considered covered, demand locations must be completely covered. The MCLP is one of the most used covering problems in the context of location theory and was originally proposed by Church and ReVelle.[98] In the problem, a set of demand nodes (OHCAs) and a set of facilities (AEDs) to be located are considered. The objective of the MCLP is to find the best locations for a fixed number of facilities to maximise the demand coverage; not every demand node will be covered. Location analysis and modelling have been used both to support prescriptive planning efforts seeking to site service facilities and to provide descriptive insights regarding the service performance of existing problems.[99] The MCLP has stood the test of time and has been integrated into several geographical information system (GIS)-based software packages.

The original optimisation work concerning the deployment of AEDs in the community was developed by Chan and colleagues in Toronto, Canada.[41,71,72,100–104] The original work developed a model to prioritise public locations for AED deployment and tested it against a population-guided approach.[71] The locations of 1310 OHCAs that occurred between 2005 and 2010 were considered, along with the locations of 1669 registered AEDs and 25,851 unique locations for businesses. They observed that 304 (23%) OHCAs occurred within 100 m of at least one registered AED, with an average distance of 281 m. However, the optimisation model said that if AEDs were deployed in the top 30 locations, an additional 112 OHCAs would be covered (32% total) and the average distance to the closest AED would be 262 m.

Further analysis of the data, with an additional 403 registered AEDs, showed that optimising the AED deployment outperformed the existing approach by 40% in coverage, and that substantial gains could be further achieved through relocating existing AEDs.[100] They concluded that improvements in survival and cost-effectiveness were possible through optimisation. Further modification to their models would account for uncertainty in future OHCA locations improving AED accessibility.[101]

Sun *et al.*[41] analysed OHCA coverage loss due to limited temporal access of 737 registered AEDs. About 18.5% of 2440 non-traumatic OHCAs were assumed to be covered, whereas about 14.5% were covered, resulting in a relative coverage loss of 21.5%. They identified 4898 businesses and public points of interest (POIs) as potential candidate locations for AED placement. Using the developed spatiotemporal model to guide deployment, a 25.3% relative increase in actual coverage was achieved compared with the spatial-only approach. When the team identified specific business franchises and municipal locations to maximise OHCA coverage, Tim Hortons (coffee shops) ranked first in the city and Starbucks ranked first downtown. Coffee shops and banks occupied 8 of the top 10 spots, and a number exhibited high temporal stability both in the city and downtown.[72]

The Toronto team examined the performance and generalisability of the spatiotemporal AED placement optimisation model developed for Toronto in Copenhagen. Looking at 2149 public OHCAs and 1573 registered AEDs, the coverage loss was found to be 24.4%. When the model was applied to the data, a coverage gain of 15.3% was achieved.[104] Further analysis found that optimised AED placements increased OHCA coverage by approximately 50–100% over real AED placements, leading to significant predicted increases in bystander defibrillation and 30-day survival.[103] Further computer modelling of the data from Copenhagen confirmed that optimised locations provided significantly higher coverage (about 10% higher), and that estimated bystander defibrillation and 30-day survival rates increased by about 3% and 1.5%, respectively.[102] The conclusion from these three studies was that it was possible to apply an optimisation model developed in Canada to data obtained in Denmark.

Further work by the team, along with colleagues in Edinburgh, sought to determine whether optimisation can improve alignment between AED locations and OHCA incidence across levels of socioeconomic deprivation in Scotland.[105] They used optimisation to determine optimal locations for placing 10%, 25%, 50% and 100% additional AEDs, as well as locations for relocating existing AEDs based on OHCAs occurring between 2011 and 2017 (OHCA occurring within 100 m of an AED), with respect to the Scottish Index of Multiple Deprivation (SIMD) quintile. The results showed that the optimised coverage more closely resembled the suspected OHCA distribution and resulted in a more equitable coverage across levels of socioeconomic deprivation.

Several other spatial and spatiotemporal mathematical models have been developed which have also demonstrated better performance than empiric population-based models for placement of public AEDs. In New Jersey, Bonnet *et al.*[106] applied the MCLP in an urban environment by using a multiobjective genetic algorithm, incorporating both the availability of AEDs and the number of AEDs as an objective function. They created two data sets, one that contained OHCA locations (demand points) and one which contained locations of 212 local restaurants and their hours of operation (potential locations). The study: (1) used route-based walking time instead of straight-line approximations; (2) introduced temporal availability in deployed devices to account for location hours of operation; (3) used multiobjective optimisation to balance decision-maker objectives; and (4) implemented an interactive decision-maker tool for observing effects on benefits and costs. This methodology simulated a 98.06-second improvement in time to retrieve an AED, which corresponded to an estimated 11.4–16.3% improvement in patient survivability.

In an urban environment in South Korea, Kwon and colleagues[107] utilised the location-allocation solver in GIS software for the placement of AEDs. Automated external defibrillators (n = 227) were already widely installed in public places, but they compared 10 different installation methods to determine if OHCA coverage could be improved. They observed that additional installation was able to cover 10–30% more OHCA cases, finding an additional 228 optimal AED locations in the study area.

In Canton Ticino, Switzerland, optimisation techniques were applied to the location of 2802 OHCAs and 719 AEDs.[108] Tierney *et al.* developed a flexible location model (FLM) for AEDs, comparing performance to existing fixed location and population models. About 23% of OHCA events occurred within 100 m of an AED, with 31% in urban and 18% in rural areas. The median distance to the nearest AED was 224 m (168 m urban, 269 m rural). The FLMs performed better, with the cost of deploying 20 new AEDs being reallocated to relocating 171 existing AEDs to new locations, improving OHCA coverage to 38%, compared to 26% using fixed models and 24% with the population-based model. They concluded by stating that the use of optimisation models for AED placement was superior to population models and should be strongly considered by communities when selecting areas for AED deployment. Further analysis of the data incorporated OHCA spatial risk factors and OHCA coverage to identify spatial regions most in need of resources, and assessed how AED allocation methods affected OHCA accessibility.[109]

In Singapore, OHCAs were stratified based on the time to defibrillation (TTD) and a regression model was developed to predict survival rates.[110] The AED placement model [maximum expected survival rate (MESR) model] was based on: (1) locations of previous OHCAs; (2) locations of existing AEDs; (3) locations of candidate points for placement of new AEDs; and (4) number of available new AEDs to be deployed. They then compared their MESR model with that developed by the Canadians and found that it outperformed the latter. The authors stressed that TTD is important, and if within 2 minutes of cardiac arrest the survival rate was 67%. It then reduced to 19% when TTD was 2–4 minutes. Regression analysis indicated that the reduction in survival chance showed an exponential reduction with every minute of delay on defibrillation.

Chapter 2 Project aims and objectives

Research question

This project asked the question, in respect of OHCAs in England: what effect would alternative models for the placement of AEDs in the community, compared to current practice, have on the proportion of OHCAs covered and the clinical and cost-effectiveness of PAD programmes?

Project aim

The project had the following aim:

- To optimise the placement of public-access AEDs in England, using mathematical modelling techniques, to maximise the likelihood that an individual suffering an OHCA will have access to a publicly accessible defibrillator, thus improving their chances of survival. To assess the cost-effectiveness of optimised public-access AED placement compared to current placement (CP).

Project objectives

This aim was achieved using the following work packages (WPs):

- WP1: determining the current coverage of known public-access AEDs relative to historical OHCAs.
- WP2a: modelling the characteristics of different deployment strategies for public-access AEDs.
- WP2b: developing a mathematical optimisation model for AED deployment, accounting for spatial and temporal accessibility.
- WP3: determining the costs and benefits associated with the placement strategies developed and compare these against current practice.
- WP4: synthesise data from WP1 to WP3 and stakeholder involvement.

Chapter 3 Methods

Work package 1

Aim and objectives

The aim of this WP was to explore the characteristics of current locations of AEDs relative to the location of cardiac arrests. This was met by completing the following objectives:

- identifying the location of all registered AEDs and historical OHCAs in England
- describing the neighbourhood characteristics of locations of registered AEDs
- determining the OHCA coverage of registered AEDs.

Automated external defibrillator information

Details of the locations of registered public-access AEDs in England were obtained for the 11 English ambulance service regions. Services maintain lists of publicly available defibrillators so that they can direct 999 callers to them in the event of an OHCA.[74] Some services make the list accessible on their website, while others were contacted directly to obtain the information after setting up a data-sharing agreement. For those that had not provided the information at the time of writing this report an OpenStreetMap project on the internet was identified, where the required information was obtained using Freedom of Information legislation (https://osm.mathmos.net/defib). Data obtained included:

- Automated external defibrillator identification number
- location address and postcode
- geographic coordinates (if available), for example latitude/longitude, easting northing.

Where possible, services were asked to provide information on AEDs registered with them as of 31 December 2019, or as close to that date as possible.

We also had discussions with the British Heart Foundation (BHF) about accessing the information it was collecting via The Circuit, the national defibrillator database (www.thecircuit.uk). It provides NHS ambulance services with vital information about where public-access AEDs are across the UK. In the time-critical event of an OHCA, it allows the ambulance dispatcher to identify whether a publicly accessible AED is available near the OHCA location so that it can be accessed quickly and used. The Circuit has been developed by the BHF in partnership with Microsoft. In 2019, The Circuit began the process of requesting all ambulance services to upload a copy of their individual AED databases and then contact the AED guardians to go on to the database to verify the details for their defibrillator. It also began a campaign to encourage all defibrillator guardians to register them on The Circuit. However, because of the COVID-19 pandemic there were significant delays in implementing the data-collection process nationally, and only recently has the last ambulance service migrated their AED database to The Circuit.

The AED location address and postcode were geocoded using Geocode, a Google Sheets add-on by Awesome Table[111] on an ambulance service basis. In some instances, obvious mistakes (< 1%) were made by this software in geocoding addresses, and these were checked manually. In addition, a sample of addresses (5%) was checked manually. The generated latitudes and longitudes were then plotted on a map to ensure that they occurred within the catchment area of that ambulance service. Any outsiders (< 1%) were again checked manually. The generated geographic coordinates were checked against those provided by the ambulance service and any discrepancies manually checked (< 1%).

The geographic coordinate of each AED was allocated to the relevant lower-level super output area (LSOA) using an Excel lookup table.[112]

Out-of-hospital cardiac arrest information

Information on OHCAs that occurred between 1 January 2014 and 31 December 2019, regardless of initial OHCA rhythm or presumed cause, and where resuscitation was continued or commenced by EMS staff, was obtained from the OHCAO registry, hosted by the University of Warwick [OHCAO (warwick.ac.uk)]. Data obtained included the:

- hour of the day, day of the week and month of year of OHCA
- location of OHCA (address, postcode) and Utstein location
- age/sex of patient
- whether the OHCA was witnessed or not
- whether bystander CPR was administered
- availability and use of public-access AED
- ambulance response time calculated from the difference between 'Clock start' and 'Clock stop' recorded in accordance with NHS England standards.

As per the AED location, the OHCA location was converted into geographic coordinates. The checks carried out were the same as those for AEDs, that is, for obvious errors in the geocoding process and outside catchment area of ambulance service. A small percentage could not be determined automatically and were checked manually.

Neighbourhood characteristics

Information on neighbourhood characteristics (2011 Census) was obtained from the Office for National Statistics (ONS) via the https://nomisweb.co.uk website for each LSOA in England, the smallest area for which all information is available in England. At the time of writing this report, full data from the 2021 Census were not available. Lower-layer super output areas were used as proxy units of neighbourhood to describe characteristics. Lower-layer super output areas have been developed by the ONS and are a geographic hierarchy designed to improve the reporting of small-area statistics.[113] They are built from clusters of contiguous output areas, which are made up of adjacent unit postcodes, and are designed to have similar population sizes and be as socially homogeneous as possible based on household tenure and dwelling type. There are 32,844 LSOAs in England with a population range of 1000–1500, and household number of 400–1200.[113] The information obtained, full definitions for which can be found at www.nomisweb.co.uk/, included:

- Residential population density, reported as the number of people per hectare. This is an estimate of the number of people living in households and those living in communal establishments.
- Workday population density, an estimate of the population during the working day. It includes everybody who works in an area, wherever they usually live, and all respondents who live in the area but do not work. The following population groups are excluded from the workday population of an area:
    - those living in England and Wales but working in Scotland, Northern Ireland, outside the UK or on offshore installations
    - those with a place of work in England and Wales but who are not usually resident in England and Wales
    - short-term residents.
- Workplace population density, an estimate of the population where the usually resident population is re-distributed to their main place of work, but those not working are excluded.
- Number and proportion of people from different ethnic groups (white, mixed race, Asian, black, other) in the resident population.
- Number and proportion of people with high education (A-level and higher), with the highest educational achievement of usual residents aged 16–74 years.
- Number and proportion of people living with a long-term health problem or disability, which classifies usual residents into three categories:
    - day-to-day activities limited a lot
    - day-to-day activities limited a little
    - day-to-day activities not limited

- Number and proportion of people in different socioeconomic groups based on occupation, which classifies usual residents aged 16–74 years by economic activity:
    - management and professional
    - intermediate
    - routine and manual
    - not working, unemployed or unknown.
- Number and proportion of people living in households classified as being deprived in none or one to four dimensions (employment, education, health and disability, household overcrowding) in any combination.
- Number and proportion of people aged < 65 years and over 65 years.
- Number and proportion of people living alone.

The Index of Multiple Deprivation (IMD) was obtained for each LSOA.[114] The index ranks every LSOA in England from 1 (most deprived area) to 32,844 (least deprived area) and is the official measure of relative deprivation for small areas (or neighbourhoods) in England. It combines information from seven domain indices, which are weighted as follows: income (22.5%); employment (22.5%); education (13.5%); health (13.5%); crime (9.3%); barriers to housing and services (9.3%); and living environment (9.3%). Each of these domains has multiple components. Deciles were created by ranking these small areas from 'most deprived' to 'least deprived' and dividing them into 10 equal groups of 3284 LSOAs (deciles 3, 4, 8 and 10 had an additional LSOA).

The rural/urban classification (RUC) for each LSOA was also obtained.

- Urban:
    - major conurbation, A1 (33.16%)
    - minor conurbation, B1 (3.48%)
    - city and town, C1 (45.25%)
    - city and town in a sparse setting, C2 (0.27%)
- Rural:
    - town and fringe, D1 (9.18%)
    - town and fringe in a sparse setting, D2 (0.57%)
    - village and dispersed (hamlets and isolated dwellings), E1 (7.16%)
    - village and dispersed (hamlets and isolated dwellings) in a sparse setting, E2 (0.94%).

Data were downloaded on 1 February 2021. We described the neighbourhood characteristics of locations where OHCAs had occurred and public-access AEDs were positioned.

Statistical analysis

All statistical analyses, unless stated otherwise, were carried out using Stata® 17.0 SE (StataCorp LP, College Station, TX, USA).

Out-of-hospital cardiac arrest and automated external defibrillator location

Descriptive statistics [mean and standard deviation (SD); median and interquartile range (IQR)] were used to describe the location of registered AEDs and where OHCAs occurred. Comparisons were made between the neighbourhood characteristics of where AEDs are located and not located (and where OHCAs had occurred and had not occurred), and with the national and regional averages for these characteristics using the t-test and chi-squared test. A stepwise logistic regression model was established to determine which characteristics influenced AED placement and OHCA occurrence. The dependent variables were whether the LSOA had an AED located within its boundary or not (yes or no), and whether an OHCA had occurred within the LSOA's boundary or not (yes or no); the independent variables were those given above. Bivariate analysis was first carried out and any variable that had a $p < 0.2$ was included in the development of the final model using a backward stepwise technique. Variables that showed significance ($p < 0.2$ here) in the univariate analysis, as well as those that were clinically important, were included for multivariate analysis.[115] In this, only variables that gave a $p < 0.05$ were included in the final model. Tests for multicollinearity between variables were carried out by calculating the variance inflation factor (VIF), a VIF > 5 suggesting there was significant correlation. Goodness-of-fit of the final model was assessed by the Hosmer–Lemeshow test.

Out-of-hospital cardiac arrest/automated external defibrillator coverage

Out-of-hospital cardiac arrest and AED locations were mapped using ArcGIS (version 10.5.1, Esri, Redlands, CA, USA) geographic information systems software, using OpenStreetMap (www.openstreetmap.org) as a base map. To identify the nearest AED to an OHCA and whether there was an AED within specified walking distances, two analyses were undertaken.

Euclidean distance

The 'Near' function in the 'Proximity' toolset of ArcGIS was used to calculate the distance (in metres) between the input features (OHCA location) and the closest feature in another layer or feature class (AED location). The geodesic method was used, which measures the shortest Euclidean (straight line) path between the two locations, considering the curvature of the earth.

Real-world walking distance

The 'Closest Facility' function of the 'Network Analysis' toolset within ArcGIS was used to determine the road/path travel distance (in metres) from each OHCA location to its nearest AED location. In this analysis we requested the function to find the nearest AED to each OHCA within a stated walking distance, without considering the time of day and day of week or traffic conditions, with no turn restrictions and the possibility of U-turns.

We estimated the number of historical OHCAs that were covered using these two methods. An OHCA was considered covered if it occurred within 100, 150, 300 and 500 m of any AED. In WP1 a 100 m coverage radius was selected as an approximation of the maximum round-trip distance a bystander could travel to retrieve and set up an AED within 3 minutes.[71,116,117] Other distances were also considered as each ambulance service has a different activation distance to send a caller to retrieve an AED during a 999 call for a cardiac arrest (see *Appendix 1*, *Table 32*).

Coverage assessment

Coverage was calculated using the definitions previously used by other studies.[41,100,104] 'Assumed coverage' was calculated on the assumption that an AED was available 24/7, and that the OHCA occurred within 100, 150, 300 or 500 m of an AED regardless of the AED's actual availability. We also calculated 'Actual coverage' where an OHCA occurred within the specified distances of an AED used to calculate assumed coverage but when the AED was available, based on the location's hours of operation. We were not able to determine the availability of the registered AEDs as this information was not accurately stored on the ambulance services' databases. We therefore assumed that they were available during normal working hours (Monday–Friday; 08.00–18.00; not bank holidays), that is, AED locations were considered inaccessible outside their hours of operation. Relative 'Coverage Loss', due to limited temporal access, was calculated by comparing the number of OHCAs that occurred within 500 m of a registered AED or POI (Assumed coverage) with the number that occurred within 500 m of a registered AED or POI when the AED was available (Actual coverage). A coverage radius of 500 m was chosen based on the radius of operation at each ambulance service (see *Appendix 1*, *Table 32*).[54] For the latter, availability was determined as normal working hours for a registered AED, or the opening hours for the POI (see *Appendix 1*, *Table 34*). The coverage loss formula used was:

$$\text{Coverage loss } (\%) = \frac{\text{Assumed coverage} - \text{Actual coverage}}{\text{Assumed coverage}} \times 100 \quad (1)$$

Coverage loss was also analysed according to geographic area, that is, urban or rural location.

'Coverage efficiency', the number of AEDs placed per covered OHCA, was calculated as the actual coverage divided by the total number of POIs. Coverage efficiency, measuring actual coverage per facility, is an indicator of how much coverage can be provided by an AED placed at a single location. Points(places)-of-interest with a high coverage efficiency tended to have fewer total POIs compared to the average. Coverage efficiency does not equal cost-effectiveness; it can be used to gauge the value of an AED placed in a specific business or municipal location. The hypothesis is that placing AEDs at POIs with high coverage efficiency will be more cost-effective than placing AEDs in locations with low coverage efficiency.

Work package 2

Aim and objectives

The aim of this WP was to compare the coverage of various AED deployment strategies and an optimisation model with current coverage. This would be achieved if the following objectives were met:

- to assess the coverage of historical OHCAs using various landmarks/buildings [points of interest (POI)] as potential locations for AEDS
- to assess the coverage of historical OHCAs using a grid-based approach as potential locations for AEDs
- to develop a mathematical model that would optimise the deployment of AEDs to enable the greatest coverage of historical OHCAs
- to compare the coverage of the different strategies and the optimisation model with current practice.

Points of interest

The Ordnance Survey's (OS) POI database was identified as a source of the required information on landmarks in England.[118] The POIs are composed of nine groups at level 1:

- accommodation, eating and drinking
- commercial services
- attractions
- sport and entertainment
- education and health
- public infrastructure
- manufacturing and production
- retail
- transport.

There are 52 categories at the second level and over 600 classes at the third level. A list of potential POI candidates was drawn up in consultation with the Steering Committee and collaborators, and also following a review of the literature.[87] The required information was obtained from the Digimap online map and data-delivery service operated by EDINA at the University of Edinburgh (https://digimap.edina.ac.uk/). Data were available as part of the 'POI' data set.[118] *Appendix 1*, *Table 33*, gives the reference code, description and number of points in England for each POI that was included in the analysis. Information obtained included:

- business name
- Point-of-interest class
- easting and northing (converted to longitude and latitude)
- address details and postcode.

Out-of-hospital cardiac arrest coverage

As in WP1, POI locations were mapped using ArcGIS geographic information system software, using OpenStreetMap (www.openstreetmap.org) as a base map. Similarly, to identify the nearest POI to an OHCA and whether there was one within walking distance (up to 500 m), two analyses were undertaken: (1) calculation of the Euclidean 'straight line' distances; and (2) calculation of 'real-world' walking distance (see *Out-of-hospital cardiac arrest/automated external defibrillator coverage*).

Grid-based strategy

We used two methods to determine the feasibility of placing AEDs in the centres of geographically defined polygons into which the whole country could be divided.

One-kilometre-square grids

It was originally planned to divide the country into 0.25 km^2 grids and assume that a defibrillator was placed in the centre of each square. Following discussion with the Steering Committee and collaborators, this was deemed uneconomical because there were approximately 521,116 0.25 km^2 grids, on the basis that the area of England is approximately 130,279 km^2. However, a data file of this information could not be found. It was therefore decided to use a 1 km^2 grid size, the smallest that could be found, as this would be more manageable analysis-wise. There are approximately 173,700 1 km^2 grids that cover England.

Census output areas

In consultation with the Steering Committee, it was agreed to also carry out an analysis using the census output area (COA) centroid. Census output areas are the smallest of the areas for which data are published by the ONS.[113] They have an average population of about 310 residents (range 100–625) and an average number of 125 households (range 40–250), covering about 0.76 km^2. They have been built up, like LSOAs, from postcode blocks with the intention of standardising population sizes, geographical shape, and social homogeneity (in terms of dwelling types and housing tenure). Urban and rural mixes are avoided where possible, with COAs preferably consisting entirely of urban postcodes or entirely of rural postcodes. As of the 2011 Census, there were 171,372 COAs for England. The centroid location for each COA was obtained from the https://data.gov.uk website.

Out-of-hospital cardiac arrest coverage

As in previous section the Euclidean and real-world walking distances between the OHCA location and the nearest 1 km^2 and COA centroid were calculated using ArcGIS.

Coverage analysis

An OHCA was deemed covered if it was within 500 m (walking distance) of an existing registered AED, as determined in WP1. We then determined if the OHCA could have been covered if it occurred within 500 m of one of the POIs or the centroid of the 1 km^2 grid square or COA. For this we estimated the probability of being covered in several ways:

- probability of being covered by a landmark/grid/COA centroid, assuming that there were no AEDs in place anywhere
- probability of being covered by a landmark/grid/COA centroid or an existing AED
- probability of being covered by a landmark/grid/COA centroid given that it was not covered by an existing AED.

As in WP1, we also calculated the 'Assumed coverage', the 'Actual coverage', 'Coverage loss' and 'Coverage efficiency'. For the POIs, we allocated an availability code based on their normal hours of operation (see *Appendix 1*, *Table 34*).

Optimisation model

We adapted mathematical optimisation models that were previously developed by project co-applicants and collaborators in Toronto, Canada,[41,71,72,100] and validated in the Netherlands,[119] Denmark[102–104] and Scotland.[105] These mathematical models were based on seminal literature in operational research, specifically within the area of facility location optimisation (MCLP).[98]

Our 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, defined as the proportion of OHCAs within a pre-specified range of any current or future AED, was maximised. More specifically, the model had the following inputs:

- addresses and hours of operation of registered AED locations (WP1)
- locations and times of historical OHCAs (WP2)

- addresses and hours of operation of candidate AED locations (WP2.1), separated into:
  - points of interest
  - points evenly spaced 1 km apart throughout each ambulance service region (1 km^2 centroid)
- a user-specified parameter *N*, which determined the number of candidate locations where AEDs are to be placed.

The model outputed the number of selected candidate locations that would maximise coverage of historical OHCAs, as well as the set of OHCAs covered by the AEDs and the total number of covered OHCAs.

We compared model outputs between the spatiotemporal optimisation model, which accounted for the hours of availability of candidate AED locations and the time of occurrence of historical OHCAs when determining coverage, and the spatial-only optimisation model, which assumed 24/7 availability of candidate AED locations and did not account for the time of occurrence of historical OHCAs when determining coverage. Up to one-half of all AEDs might have been behind locked doors or inaccessible to responders during evenings and weekends.[41,57] Accounting for the temporal availability of candidate AED locations within the optimisation modelling can lead to AED placements that overcome limitations in spatial-only coverage and maximise the spatiotemporal coverage for OHCAs, leading to more representative measures of actual AED accessibility for OHCA.[41]

Both models were evaluated on the improvement in OHCA coverage on top of baseline-level coverage provided to historical OHCAs in England by existing registered AEDs (WP1 and model input no. 1). To ensure that the evaluation of both models was not biased towards inputted data, we used an approach called '*k*'-fold cross validation, in which historical OHCAs were randomly partitioned into '*k*' equal-sized subsamples. In each of '*k*' iterations (or 'folds'), '*k*−1' subsamples of historical OHCAs (model output no. 2) were used to select optimal locations for AED placement from the set of candidate AED locations (model input no. 3). The selected AED locations within each fold were then validated using the one remaining subsample of historical OHCAs to determine the coverage level for that fold. This process was repeated '*k*' times, each time with a different validation subsample, with results across all '*k*' folds aggregated to determine the overall coverage performance provided by each model. The value of '*k*' was commonly defined as 10 but varied based on the number of OHCAs available. The '*k*'-fold cross validation approach was used for a range of values for the number of optimised AED locations *N* (model input no. 4) to determine coverage performance as a function of *N*. The values of *N* used depended on the total number of candidate AED locations available. Finally, the output of each model was analysed to consider location and ambulance response time characteristics of selected AED locations as well as locations of covered and uncovered OHCAs.

For both the spatiotemporal and spatial-only models, we computed the coverage gain for each value of *N*-optimised AED locations, defined as the increase in the proportion of covered OHCAs compared to the baseline coverage provided by the existing registered AEDs. We also compared the incremental gain in spatiotemporal coverage provided by the spatiotemporal model when compared to the output of the spatial-only model to determine the added value of using the spatiotemporal model above the spatial-only model. For each value of *N*-optimised AED locations, we reported the average and 95% CI for overall coverage gain as well as coverage gain subdivided by time of day, day of week, and area. Overall OHCA coverages of each placement strategy were tested against each other using the McNemar test for paired proportions,[120] which has been used in previous literature comparing AED placement methods.[41,71,102,103]

Work package 3: cost-effectiveness

Aim and objectives

The aim of this WP was to determine the costs and benefits associated with public AED placement strategies in each of a series of POIs as examined in WP2 (referred to as alternative-placement strategies) and compare these against current AED placement. To do so, we carried out an economic evaluation – in the form of cost-effectiveness and cost-utility analyses – using decision-analytic modelling.

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. Due to the lack of available data at the time of the analysis, a comparison of a placement based on the optimisation model (see *Optimisation model*) against CP, or POI placement, was not possible. The model was developed in line with recommended 'good practice' guidelines[121,122] and, where relevant and possible, in accordance with requirements for economic evaluation aiming to inform decision-making in the UK.[123] The model was built in Microsoft Excel® (MS Excel 365, version 2307, Microsoft Corporation, Redmond, WA, USA).

The population of interest was an annual cohort of 32,000 EMS-attended patients experiencing an OHCA in the UK.[1] A broad perspective was specified which included outcomes accruing to OHCA patients and costs borne by the healthcare system and entities supporting the purchase and deployment of AEDs. Results were expressed primarily as cost per additional quality-adjusted life-year (QALY) and as cost per life-year gained (LYG). The analysis was guided by a health economic analysis plan described in the original project proposal.

In line with recommendations, base-case analysis results – which are based on parameters that are considered most relevant and appropriate – are complemented by scenario analyses and probabilistic and deterministic sensitivity analyses.[124]

Model structure

The constructed model used a hybrid structure, comprising a short-term and a long-term part. The short-term part was operationalised through a decision tree modelling costs and outcomes arising between OHCA and hospital discharge or death prior to hospital discharge. The long-term part of the model was represented by a Markov model tracing longer-term costs and benefits occurring over a specific time horizon after hospital discharge (10 years in base-case analysis).

A graphical representation of the decision model can be seen in *Appendix 2*, *Figure 19*. The model follows a cohort of patients experiencing an OHCA, and each time it runs it calculates expected costs and benefits accruing under each of two different 'states of the world': (1) CP, a state with current AED availability; and (2) alternative placement, a state where additional AEDs have been deployed in each of 14 specified POIs.

The decision tree branches modelling each alternative (i.e. top and bottom branch in *Appendix 2*, *Figure 18*) are identical in structure but differ in terms of probabilities of following different paths. Total expected costs and benefits were calculated using standard ('roll-back') methods.[122]

At the end of the decision tree (i.e. the short-term part), simulated patients who have survived to hospital discharge enter a Markov model (long-term part, given in *Appendix 2*, *Figure 19*) which calculates term costs and benefits accruing over the remaining time horizon depending on their functional status. The model comprises five health states relating to status at hospital discharge determined by the cerebral performance category (CPC) score. Cerebral performance category is a commonly used classification of functional status for patients with cardiovascular conditions, with CPC scores ranging from 1 (good cerebral performance) to 5 (death) and corresponding model states being CPC1, CPC2, CPC3, CPC4 and Death. The Markov model was evaluated using 1-year cycles, within which patients in a health state corresponding to a CPC score could remain in the health state or move to the absorbing state Death, similarly to available models in the literature.[125,126]

Model inputs

The model was populated with three main categories of inputs: probabilities of moving to a health state or experiencing an event, costs incurred at different health states or events, and outcomes associated with different health states or events. These are described below.

Probabilities

Values for the short-term (decision tree) part of the model were obtained from a variety of sources. Probabilities related to availability of AEDs under alternative-placement scenarios (POI) were obtained from WP2 of this project (see *Appendix 2*, *Table 35*). In the base-case analysis, these probabilities were calculated according to the historical number of OHCAs occurring within 500 m of the AED, considering the availability of existing AEDs and accounting for the fact that AEDs in specific locations are not available on a 24/7 basis. Different specifications were explored in scenario analyses.

Probability values for an AED being used if an AED was (or became) available within 500 m, an OHCA patient having arrived at hospital alive and a patient having been discharged alive, came from the OHCAO registry maintained by the University of Warwick and containing details of all OHCAs where EMS started or continued resuscitation attempts.[1,2,127] Probability values used in the model can be seen in *Appendix 2*, *Table 36*.

Probabilities for the long-term part (Markov model) were obtained from the literature. First, patients surviving post-hospital discharge were categorised in a particular CPC score according to proportions taken from a recent UK study by Petrie *et al.*[128] Within each model cycle, those patients were modelled to either remain alive in the same functional state or die, using different probabilities for the first and subsequent years.[129] This effectively assumed that patients could not move to another functional status (i.e. do not improve or deteriorate) in each cycle. This restrictive assumption was made because of a lack of robust data on transitions between functional status and the same assumption has inevitably been made by recent economic models on the topic.[126,130]

Resource use and costs

To reflect costs borne by various relevant entities (e.g. costs related to installation and maintenance of AEDs, and cost of OHCA patient care), the analysis adopted a perspective that included costs incurred within and outside the healthcare system.

Care received and its associated cost were calculated over the specified time horizon. During the short-term period, these included:

- the cost of additional AEDs per OHCA, which included costs due to purchase and installation, maintenance (replacement of batteries and pads) and use (e.g. replacement of pads)
- the cost of advanced life support provided as part of EMSs care (which includes staff, vehicles and fuel, buildings, equipment, and dispatch centre costs)
- the cost of emergency medicine services when an OHCA patient arrives dead
- the cost of in-hospital post-cardiac arrest care for a patient who died in the hospital or was discharged alive
- healthcare costs after hospital discharge, depending on CPC score at discharge.

The cost of the deployment of additional defibrillators at particular POIs was applied to the 'intervention' branch of the model only. It was assumed that the life span of a defibrillator was 10 years (varied in sensitivity analysis). The cost of installing and maintaining an AED was calculated as the sum of the equivalent annual cost (EAC) over 10 years. To convert this to a value that could be added to the total expected cost per OHCA over the time horizon, this was then divided by the number of OHCAs over 10 years, to give the per-patient cost due to installation and maintenance of additional AEDs. Costs of past replacement resulting from using an AED were also assigned to the relevant branches of the model (i.e. where an AED was available and was used).

Cost of pre-hospital EMS care offered by trained paramedics was taken from a recent study reporting the costs of pre-hospital advanced life support for OHCA in the UK.[131] Accidents and emergency costs for OHCA patients who presented dead on arrival were taken from NHS Reference Cost Schedules.[132] Costs of in-hospital cardiac arrest care, stratified according to whether the patient was discharged alive or died before discharge, were taken from a UK study that calculated hospital costs of OHCA patients.[128] Healthcare costs due to care provided after hospital discharge were taken from the literature, and were stratified by neurological outcome (CPC 1 or 2 and CPC 3 or 4).[133] Costs associated with productivity loss due to mortality and morbidity were not accounted for, as these were considered to be largely inconsequential.[126]

All costs are presented in 2019–20 Great British pounds (GBP) (£). When needed, values in the literature were converted to pounds using Bank of England historic exchange rates[134] and inflation rates from the NHS cost inflation index (NHSCII).[135] Resource use and cost inputs used in the model are given in *Appendix 2*, *Table 37*.

Outcomes

Outcomes were presented in term of QALYs and life-years gained. QALYs are the product of two quantities: the time that a patient spends in a particular health state and the preference-based health-related quality of life (often referred to as 'utility') associated with the particular health state.[122]

Quality-adjusted life-years were calculated throughout the short-term and long-term periods of the model, over the specified time horizon (10 years in the base-case analysis). Utility indices associated with different health states in the model were obtained from the literature or calculated based on values in the literature. Indices were specified for the following health states: (1) receiving emergency care; (2) patient stabilised and treated in hospital; (3) discharged from hospital; (4) patient categorised in each of CPC1, CPC2, CPC3 and CPC4 during the first year after hospital discharge; (5) patient categorised in each of CPC1, CPC2, CPC3 and CPC4 beyond the first year after hospital discharge; and (6) patient is deceased (see *Appendix 2*, *Table 38*). Estimates of health-related quality of life in patients classified as CPC4 are, to the best of our knowledge, not available. A patient classified in CPC4 presents 'unawareness, even if appears wake (vegetative state) without interaction with the environment'. A value of 0 has been assigned to this state in the literature[126] and we used this value in the analysis. These values were subsequently varied in probabilistic and deterministic sensitivity analyses.

Other inputs

Other inputs, necessary for operationalising the model, were included in the calculations. These included the average length of hospital stay (effectively, the time horizon for the short-term part of the model), the number of additional AEDs needed for each alternative placement (which enables calculating the additional cost of each assessed alternative placement), the annual population of OHCAs of interest, the effective lifetime of an AED and the discount rate for costs and outcomes.

The average length of hospital stay after admission following an OHCA was obtained from the OHCA database[2] and was dependent on whether the patient died while in hospital or was discharged alive. The latter value indicated the time horizon for the short-term part of the model.

The numbers of additional AEDs that would need to be deployed for the employed coverage (probability of an AED being available) variables to apply were generated in WP2 of the report and can be found in the last column of *Table 35* in *Appendix 2*.

The study population of interest, that is all EMS-attended OHCAs where resuscitation was attempted, was taken from the OHCAO report detailing the number of OHCAs collected, based on 11 English ambulance services.[18] Costs (and outcomes) accruing beyond the first year were discounted at an annual rate of 3.5%.[123]

Sensitivity analyses

In line with recommendations, uncertainty in the model was propagated through different types of sensitivity analyses.[124]

Probabilistic sensitivity analysis (PSA) was carried out where key input variables were assigned probability distributions to account for parameter uncertainty in available estimates.[136] Running the PSA involved 5000 iterations, in each of which a set of values was drawn through Monte Carlo simulations. Different numbers of simulations (7500 and 10,000) were undertaken to assess convergence. For each iteration, results were re-calculated and recorded to give a distribution of the costs and effects associated with each comparator. The variables subjected to PSA, as well as the distribution and parameters attached to them, are given in *Appendix 2*, *Table 39*. Distributions for parameters were selected according to the type of parameter (e.g. probability, cost, utility value), in line with recommendations in the published literature.[137]

Deterministic sensitivity analyses were carried out by replacing the base-case values by alternative values to explore the impact of these changes in the results. These included one-way sensitivity analyses (where one variable was varied at a time) and multiway sensitivity analyses (where more than one parameter was varied at the same time) in cases where this was considered necessary (e.g. when variables were interconnected).

Scenario analyses were carried out to generate and present results based on different assumptions or configurations, which affected the probability that an AED is available within a given distance of an OHCA. The following key assumptions were specified and explored: (1) probability of an AED being available depends on 24/7 coverage; (2) reference distance from an OHCA to AED set to 100 m and (3) reference distance from an OHCA to AED set to 1000 m. These gave rise to three scenarios: (1) probability of an AED being available within 500 m assuming 24/7 coverage; (2) probability of an AED being available within 100 m (assuming actual coverage); and (3) probability of an AED being available within 1000 m (assuming actual coverage). Probabilities of AED being available for different scenario analyses and numbers of additional AEDs needed for each compared placement employed in these three scenarios, are given in *Appendix 2*, *Table 40*.

Due to the volume of sensitivity analyses and in the interests of keeping the analysis focused, only sensitivity analyses undertaken on the placement that was found to be the most cost-effective are reported here.

Presentation of results

Base-case results are presented in the form of total expected costs, total expected outcomes (QALYs and LYG) and incremental cost per additional outcome [incremental cost-effectiveness ratio (ICER), in terms of QALY and LYG]. The distributions of total expected costs and total per-patient outcomes generated through PSA are used to construct 95% CIs, and the joint distribution of cost per outcome pairs is presented in cost-effectiveness planes which are plotted in cost-effectiveness acceptability curves (CEACs). Cost-effectiveness acceptability curves show the probability of an alternative-placement strategy being cost-effective when compared to CP across a range of possible values of 'willingness to pay' (a.k.a. ceiling ratios) for an additional unit of outcome.[138] To aid interpretation, and in the absence of specific values of maximum acceptable ICER, we compare ICERs against the range of £20,000–30,000 per QALY mentioned in the National Institute for Health and Care Excellence (NICE) Guide to Methods for Technology Appraisal.[123] Using the range specified by NICE as a reference is common, even when interventions are not evaluated as part of the NICE Technology Appraisal process for which NICE guidance has been issued. However, it must be noted that whether an intervention is considered cost-effective or not should depend on the views of the decision-makers considering a particular allocation of funds. Additionally, caution is needed in describing interventions with ICERs over this value as not cost-effective as, even in the case of NICE, it is emphasised that the £20,000–30,000 per QALY range is not prescriptive and interventions that result in ICERs above this are not automatically seen as 'not cost-effective'.[123]

Value-of-information analysis

Using the developed model, value-of-information analysis was carried out to determine the value of conducting primary research to calculate expected value of perfect information (EVPI) estimates and determine the value of pursuing further evidence.[139,140] Expected value of perfect information is simply the difference between the (expected net) benefits that would accrue from a decision with no uncertainty ('perfect' information is available) and the (expected net) benefits from the same decision, this time made based on current (considered imperfect) information. In simple terms, unless a decision (e.g. an intervention adoption decision) is made under complete certainty, there will always be a possibility that the decision is 'wrong' (i.e. does not lead to maximum benefits). Thus, the EVPI is a construct that represents the amount of benefit that a decision-maker is expected to forfeit by making an adoption decision on the basis of an analysis where, inevitably, many of the input parameters are not known with certainty (e.g. due to inherent sampling uncertainty). To estimate this, the expected benefit of a decision made under some uncertainty (i.e. with current information) is compared to the expected benefit that would be realised in a (hypothetical and largely unattainable) situation where there is no uncertainty (i.e. there is perfect information, that is, every parameter in the analysis is known with complete certainty).

In this sense, the EVPI associated with a particular decision (e.g. to install additional AEDs in a particular POI) represents the maximum expected benefits that could be ever realised by conducting research, eliminating uncertainty and informing the adoption decision. Expected value of perfect information is typically calculated for a single decision (i.e. an individual patient) but, as information can be disseminated freely, EVPI can be extrapolated to the population of patients who are anticipated to be affected by the treatment decision, to give the population EVPI. Population EVPI was calculated by projecting the individual EVPI to the population of current and future patients which is expected to be affected by the availability of AEDs: based on a base-case time horizon (10 years), the population of interest in this analysis (31,698 OHCA cases a year), a discount rate of 3.5% per annum[123] and perfect implementation.[141]

Work package 4: data synthesis and stakeholder meeting

Aim and objectives

The aim of this WP was to bring together interested stakeholders to a location where the findings of WPs 1, 2 and 3 were presented, discussed and synthesised to develop a national consensus of the optimal location for public-access AEDs. This was achieved by completing the following objectives:

- present a synthesis of the evidence from previous WPs
- develop a guidance document to advise key stakeholders on the optimal location for AEDs
- develop a final report for submission to National Institute for Health and Care Research (NIHR) Health and Social Care Delivery Research programme
- identify priorities for future research.

Plan of investigation

A hybrid meeting was held on 7 December 2022 at the University of Warwick's conference facilities. Stakeholders attending represented the following organisations:

- Public-access-defibrillation-optimisation study co-applicants [Universities of Warwick, Southampton, Lincoln, Edinburgh, Toronto, Kingston (Ontario), and patient and public involvement (PPI) representative]
- Public-access-defibrillation-optimisation study Steering Committee (NHS England, Scottish Ambulance Service, University of Sheffield, PPI representative)
- British Heart Foundation
- Resuscitation Council UK(RCUK)
- NHS England
- Association of Ambulance Chief Executives
- South-East Coast Ambulance Service (SECAmb)
- Queen's University, Belfast
- Northern Ireland Ambulance Service
- St. John Ambulance Service
- Charities:
    - Sudden Cardiac Arrest UK.
    - Sudden Arrhythmic Deaths (SADS) UK.

There was a total of 35 attendees, with 21 in-person and 14 virtually via Teams.

The agenda for the meeting was:

- Context and meeting objectives: the current OHCA epidemiology was presented, highlighting the number of annuals cases, where they occurred, the survival rate by ambulance response time and impact of various bystander interventions; the improvement in bystander CPR rate over the years; and use of public access defibrillators.[2] The Circuit was then briefly described and the importance of AED registration stressed. ILCOR's innovative approaches to PAD were introduced.[142]
- Public-access defibrillation – what the existing evidence tells us. A review of the current published evidence was presented: (1) probability of defibrillation relative to AED retrieval distance; (2) impact of AED range on OHCA coverage; (3) AED retrieval distance and OHCA survival; (4) optimal AED density in community; and (5) identification of locations for AEDs.
- WP1: current situation – data were presented on the current coverage of historical OHCAs by AEDs that were registered with ambulance services as of 31 December 2019.
- WP2: comparison of deployment strategies – data were presented on the coverage of historical OHCAs if AEDs were deployed at various POIs, the centroid of a 1 km^2 grid or COA.
- WP2: optimisation model – data were presented on the coverage of historical OHCAs using a mathematical optimisation model.

- WP3: cost-effectiveness analysis – presentation of the cost-effectiveness of the deployment strategies analysed in WPs 1 and 2.
- Group work exercise: the attendees were split up into three groups to discuss the topics listed below. They were given about 30 minutes to discuss the topic and highlight the main messages required to answer each question. One person was nominated to summarise and present these messages. Where possible, members from the same organisation were split between the groups.
    - What strategies should be used to increase the distribution of AEDs in communities?
    - What guidance should be provided for where to place AEDs in communities?
    - What further research is required?

After the meeting we reviewed the meeting notes and records to check process and interpretation. If any problems were identified, these were resolved through e-mail contact with participants. Notes were analysed to further inform the final report and guidance documentation.

Patient and public involvement

The approach to PPI was informed by the INVOLVE briefing notes for researchers[143] and our experience of working with PPI to address complex and challenging issues relating to the care of patients with cardiac arrest.

The PPI co-applicant, John Long, was involved since the conception of the study and made a valuable contribution in the development of the proposal, and reviewed and commented on work at various stages of the project. Mr Long developed and presented the proposal to the Clinical Research Ambassador Group (CRAG), based at the University Hospitals Birmingham NHS Foundation Trust, previously Heart of England NHS Foundation Trust. The research team also presented an update of the work to CRAG members in 2021. Invaluable feedback from this group helped us to shape the proposal that we believed addressed an important question for patients, healthcare providers, the NHS, and charities in a sensitive manner. They also provided advice on how to present results.

There was PPI involvement as part of the Steering Committee, through Neil Morris and Rosemary Wilson. They provided comment and advice throughout the project.

A stakeholder meeting was held in December 2022 to discuss the findings of the research and advise on the way forward to improve the deployment of AEDs within all UK communities. John Long attended this workshop, as did members of charities with an interest in cardiac arrest. Anne Jolley (MBE) and John Jolley (MBE) from Sudden Arrhythmic Death (SADS-UK) and Paul Swindell from Sudden Cardiac Arrest UK were in attendance, along with Mr Long, and provided valuable feedback. John Long commented that there was very clear support for the work carried out by the study and an endorsement of the recommendation to find a way to better place AEDs within all communities in the UK. A number of sound suggestions were made by attendees on suitable sites for AEDs and positive recommendations of encouraging public participation in CPR and AED training programmes.

Chapter 4 Results

Work package 1: current out-of-hospital cardiac arrest coverage

This WP explores the characteristics of current locations of AEDs relative to the location of cardiac arrests. It considers the location of all registered AEDs and historical OHCAs in England, the neighbourhood characteristics of locations of registered AEDs and the proportion of OHCAs covered by registered AEDs.

Out-of-hospital cardiac arrest

Out-of-hospital cardiac arrest demographics

Details of 170,764 OHCAs were obtained from the OHCAO registry for all 11 English ambulance services that covered the period 1 January 2014–31 December 2019 (*Table 1*). In about 86.2% of these cases (*n* = 147,278) we were able to get the geographic coordinates of the OHCA location. The proportion of events in each service we were able to geocode was variable and has changed over time, ranging from 25.7% (*n* = 5202) in East of England Ambulance Service (EEAS) to nearly 100% (*n* = 26,236) in London Ambulance Service (LAS), North-East Ambulance Service (NEAS), North-West Ambulance Service (NWAS), South-Western Ambulance Service (SWAST) and West Midlands Ambulance Service (WMAS). Isle of Wight Ambulance Service (IOWAS) has been sending data to the registry only since April 2018; Yorkshire Ambulance Service (YAS) stopped sending data in September 2015 and restarted again in April 2018. The quality of location data from SCAS and SECAmb is variable.

Table 2 shows the demographics of the OHCAs that were included in the coverage analysis. Briefly, OHCAs were predominantly male (61.5%), with just over 61% aged 64 years and over. Similar proportions were witnessed by a bystander (44.4%) or not witnessed at all (42.5%), with just under 13% of OHCAs being witnessed by the EMS. About 71% of cases were known to be of medical aetiology, and those cases where no aetiology was recorded were presumed to be of medical aetiology according to the Utstein rules. About 55% of all cases received CPR from a bystander, which increased to 63% in non-EMS-witnessed cases and 69% if the event was witnessed by a bystander. Just over 20% presented with a shockable rhythm, while for unwitnessed cases the rate was 11.1% and bystander-witnessed cases it

TABLE 1 Number of OHCAs where resuscitation was attempted by EMS and details submitted to OHCAO registry, 2014–9

Service	Total number of OHCAs	Location information available, *N* (%)	Population served	Area covered (km^2)
EEAS	20,251	5202 (25.7)	6,201,214	19,500
EMAS	13,963	11,665 (83.5)	5,135,975	16,600
IOWAS	226	182 (80.5)	141,538	380
LAS	26,253	26,236 (98.9)	8,908,081	600
NEAS	11,459	11,330 (98.9)	2,657,909	8300
NWAS	21,989	21,987 (99.9)	7,292,093	14,000
SCAS	9971	7886 (79.1)	4,251,838	9200
SECAmb	16,623	13,270 (79.8)	4,740,249	9300
SWAST	17,596	17,537 (99.7)	5,599,735	24,700
WMAS	22,454	22,444 (99.9)	5,900,757	13,000
YAS	9979	9539 (95.6)	5,119,010	15,540
Total	170,764	147,278 (86.2)	55,806,861	131,120

TABLE 2 Demographic information of 147,278 OHCAs included in analysis

	Number	Percentage
Gender		
Male	90,509	61.5
Female	51,617	35.0
Unknown	5152	3.5
Age group (years)		
< 15	3209	2.2
15–34	6833	4.6
35–64	41,897	28.5
64–84	65,278	44.3
85 +	25,175	17.1
Unknown	4886	3.3
Witness status		
Not witnessed	62,589	42.5
Bystander-witnessed	65,356	44.4
EMS-witnessed	19,067	12.9
Unknown	266	0.2
Aetiology		
Medical	104,295	70.8
Trauma	128	2.8
Asphyxia	4088	2.8
Other (non-cardiac)[a]	13,215	9.0
Not recorded/unknown	21,552	14.6
Shockable rhythm		
No	104,515	71.0
Yes	30,477	20.7
Unknown	12,286	8.3
Bystander CPR		
No	65,588	44.5
Yes		
All	81,424	55.3
Non-EMS-witnessed (*n* = 128,211)	80,277	62.7
Bystander-witnessed (*n* = 65,356)	45,169	69.1
Unknown	266	0.2

continued

TABLE 2 Demographic information of 147,278 OHCAs included in analysis (*continued*)

	Number	Percentage
Public-access AED availability		
No	31,311	21.3
Yes	2805	1.9
Unknown	113,162	76.8
Public-access AED used		
No	101,558	69.0
Yes		
All	4820	3.3
Public-access AED not available (*n* = 144,473)	3184	2.2
Public-access AED available (*n* = 2805)	1645	58.7
Unknown	40,891	27.7
ROSC at hospital handover		
No	97,115	65.9
Yes	39,633	26.9
Unknown	10,530	4.2
Survival to hospital discharge		
No	109,628	74.4
Yes	12,161	8.3
Unknown	25,489	17.3

a Includes drowning, drug overdose, exsanguination, electrocution.

was 28.7%. Ambulance services indicated the availability of a public-access defibrillator was low, at 1.9%, but use of one was at 3.3%. Use in bystander-witnessed cases was slightly higher at 4.9%. However, the reporting of this information has been indicated as incomplete. The rate of ROSC at hospital handover was 26.9%, 34.9% in cases that were witnessed by a bystander and where the bystander gave CPR, and 43.6% in those where a defibrillator was also used. Survival to hospital discharge was 8.3% overall, 10.8% in cases witnessed by a bystander and where CPR was given, and 21.2% in cases where a defibrillator was also used.

Temporal variability of out-of-hospital cardiac arrest events

Hour of the day

Table 3 shows that about 13% of all cases occurred in the early hours of the morning (midnight to 06.00), with the proportion doubling during the other 6-hour periods. There was significant variability in the hour of the day when an OHCA occurred (see *Appendix 3*, *Figure 20* and *Table 41*). In the early hours of the morning, the proportion of all cases remained around 2.2% up until 06.00, after which there was a steady increase to a peak of 6.0% at around 10.00. Thereafter, there was a small decline until around 16.00, when there was another smaller peak. From 18.00 and into the evening/night the percentage gently decreased.

Day of the week

There was also significant variability in the day of the week when an OHCA occurred (*Figure 2*). There was a peak of around 14.8% on a Sunday after which the percentage declined to a minimum of about 13.9% on a Wednesday/Thursday, after which it then increased on a Friday/Saturday. About 29% of all OHCAs occurred at the weekend (see also *Appendix 3*, *Table 42*).

TABLE 3 Number and proportion of OHCAs that occurred by 6-hour call period

Call period	Number	Proportion (%)
00.00–05.59	19,503	13.2
06.00–11.59	43,944	29.8
12.00–17.59	39,043	26.5
18.00–23.59	34,651	23.5
Unknown	10,137	6.9
Total	147,278	100.00

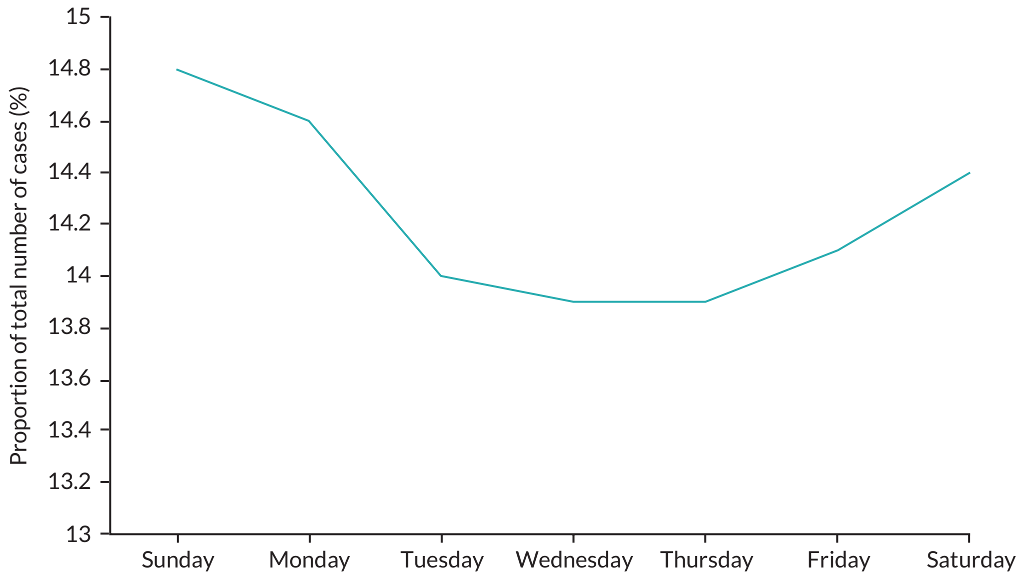

FIGURE 2 Day of the week on which OHCAs occur.

Hour of day and day of week

Throughout the week, significantly fewer OHCAs occurred between 00.00 and 05.59 compared to the rest of the day (see *Appendix 3*, *Table 43*). The percentage of cases rose between 06.00 and 11.59, and dropped in the afternoon (12.00–17.59), and then rose again in the evening (18.00–23.59). These data are shown graphically in *Appendix 3*, *Figure 21*. A total of 46,239 (31.4%) of all OHCAs occurred outside normal working hours (08.00–18.00, Monday–Friday).

Month of the year

More OHCAs occurred during the winter months (October–January), with a drop in spring (February–March) and summer (June–September) (see *Appendix 3*, *Figure 22*).

Neighbourhood characteristics of out-of-hospital cardiac arrest locations

Out-of-hospital cardiac arrests occurred in LSOAs, compared to the national average, that had a slightly larger residential population density (45.4 per 100,000 vs. 42.6 per 100,000) and a significantly greater working-day population density (46.7 per 100,000 vs. 38.6 per 100,000) and workplace population density (22.2 per 100,000 vs. 16.1 per 100,000) (*Table 4*). There was also a small, but significant, increase in the proportion of people aged 65 years and over (17.0% vs. 16.6%). There was a lower percentage of people of white ethnic background in these areas (84.6% vs. 86.2%) and a greater percentage of non-white background (13.3% vs. 11.6%). These areas also had more people in

TABLE 4 Comparison of neighbourhood characteristics of OHCA and AED locations with the national LSOA average (numbers are percentages unless otherwise stated)

Characteristic	OHCA locations (*n* = 147,278)		National LSOA average (*n* = 32,844)		LSOA where OHCA occurred (*n* = 30,709)	LSOA where OHCA did not occur (*n* = 2135)
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Mean (SD)
Population density (N/hectare)						
Residential	45.4 (43.0)*	37.1 (15.2–59.9)	42.6 (42.3)	34.5 (12.3–57.3)	43.3 (42.5)*	33.2 (36.8)
Workday	46.7 (77.2)*	32.1 (14.0–52.9)	38.6 (53.1)	28.7 (10.8–47.0)	39.3 (54.0)*	28.2 (34.8)
Workplace	22.2 (69.5)*	8.4 (3.5–19.6)	16.1 (42.2)	7.2 (2.9–16.2)	16.4 (43.2)*	11.8 (23.1)
Age group (years)						
< 65	83.0 (7.5)*	83.6 (78.4–88.5)	83.6 (7.2)	83.9 (78.8–88.7)	83.3 (7.2)* 16.7 (7.2)*	84.4 (7.0) 15.5 (7.0)
≥ 65	17.0 (7.5)*	16.4 (11.5–21.6)	16.6 (7.2)	16.1 (11.3–21.2)		
Ethnic group						
White	84.6 (20.5)*	94.7 (79.6–97.8)	86.2 (18.7)	94.9 (83.3–97.7)	86.0 (19.0)*	89.7 (13.2)
Mixed	2.3 (2.0)*	1.5 (0.8–3.2)	2.2 (1.9)	1.5 (0.8–2.9)	2.2 (1.9)*	2.0 (1.6)
Non-white	13.3 (19.3)*	3.8 (1.3–17.0)	11.6 (17.5)	3.6 (1.3–13.4)	11.9 (17.8)*	8.2 (12.2)
Socioeconomic classification						
Management/professional	29.6 (12.1)*	28.4 (20.2–37.8)	31.3 (12.2)	30.5 (21.9–39.8)	31.0 (12.2)*	35.0 (11.8)
Intermediate	27.7 (6.1)*	28.4 (23.7–32.1)	29.4 (5.5)	30.2 (26.2–33.2)	28.0 (5.6)*	30.1 (5.9)
Routine/manual	26.7 (10.3)*	26.1 (18.8–34.5)	25.4 (10.1)	24.6 (17.6–32.6)	25.7 (10.2)*	22.4 (9.4)
Unemployed/not classified	14.8 (9.4)*	11.7 (8.7–17.9)	14.0 (9.2)	10.8 (8.4–16.2)	14.1 (9.2)*	12.4 (10.1)
Long-term health limits day-to-day activity a lot	9.2 (3.7)	8.7 (6.5–11.3)	8.4 (3.5)	7.9 (5.9–10.4)	8.5 (3.5)	6.7 (3.0)
Education, A-level and above	43.7 (13.8)	42.0 (33.6–52.0)	44.8 (13.7)	43.3 (34.9–52.9)	44.6 (13.6)	47.3 (13.7)
Not living as a couple	43.8 (10.8)	42.7 (35.0–51.0)	42.1 (10.8)	40.4 (33.4–48.8)	42.3 (10.7)*	38.6 (10.5)

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TABLE 4 Comparison of neighbourhood characteristics of OHCA and AED locations with the national LSOA average (numbers are percentages unless otherwise stated) (*continued*)

	OHCA locations (*n* = 147,278)		National LSOA average (*n* = 32,844)		LSOA where OHCA occurred (*n* = 30,709)	LSOA where OHCA did not occur (*n* = 2135)
Characteristic	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Mean (SD)**
No. of dimensions households are deprived						
None	40.1 (12.0)*	40.3 (30.8–49.2)	42.7 (12.2)	43.4 (33.5–51.9)	42.3 (12.2)*	48.3 (11.5)
1	33.0 (3.6)*	32.9 (30.7–35.1)	32.6 (3.7)	32.6 (30.4–34.9)	32.7 (3.7)*	31.9 (4.3)
2	20.5 (7.1)*	20.2 (15.0–25.8)	19.1 (7.0)	18.5 (13.6–24.2)	19.3 (7.0)*	15.9 (6.3)
3	5.8 (4.0)*	4.7 (2.5–8.3)	5.1 (3.8)	4.0 (2.1–7.2)	5.2 (3.8)*	3.6 (2.8)
4	0.6 (0.7)*	0.4 (0.1–0.9)	0.5 (0.6)	0.3 (0.1–0.7)	0.5 (0.6)*	0.3 (0.5)
IMD						
Rank	14,690 (9398)*	13,837 (6490–22,542)	16,423 (9481)	16,423 (8212–24,634)	16,171 (9487)*	20,029 (8636)
Decile	5.0 (2.8)*	5.0 (2.0–7.0)	5.5 (2.9)	5.5 (3.0–8.0)	5.4 (2.9)*	6.6 (2.6)

* $p < 0.001$.

routine/manual occupations (26.7% vs. 25.4%) and unemployed (14.8% vs. 14.0%). The areas were also significantly more deprived (IMD rank 14,690 vs. 16,423; IMD decile 5.0 vs. 5.5).

When comparing the characteristics of where OHCAs had and had not occurred, the former had a significantly larger population density (see *Table 4*). There were also a greater proportion of people aged 65 years and over (16.7% vs. 15.8%), a greater proportion of people of mixed ethnicity (2.2% vs. 2.0%) and non-white (11.8% vs. 8.4%) ethnicity, a greater proportion of individuals in routine/manual occupations (25.7% vs. 22.5%) and unemployed (14.1% vs. 12.4%), and a greater degree of deprivation (IMD decile 5.4 vs. 6.5).

Figure 3 shows how the mean and median LSOA OHCA incidence decreases with increasing level of affluence.

Out-of-hospital cardiac arrest logistic regression analysis

Logistic regression analysis was carried out to determine which characteristics had the greatest impact on where an OHCA had occurred. In the bivariate analysis all variables were statistically significantly related to whether an OHCA had occurred in the LSOA (see *Appendix 4*). Following backward stepwise logistic regression analysis, setting the *p*-value for exclusion at 0.05 and checking for collinearity between variables, the final model in *Table 5* was obtained. The likelihood of an OHCA occurring in an LSOA increased with increasing workday population density, the proportion of people aged 65 years and over, and the proportion of people of non-white ethnic groups of that LSOA. The likelihood decreased with the proportion of people in intermediate occupations and unemployed/not classified, and the proportion of people in mixed ethnic groups. The probability also increased with increasing level of deprivation, that is, the higher the IMD decile, the lower the odds of OHCA (*Figure 4*).

Automated external defibrillators

A total of 32,491 AEDs were known to the English ambulance services as of 31 December 2019 (*Table 6*). The number varied between ambulance services, with a range of 159–5891. Of these, it was not possible to determine the LSOA in which they were located for 98, because of incomplete or no address, they were mobile units, or they were in Wales or Guernsey. A total of 32,393 AEDs were included in this analysis. The population coverage for these AEDs ranged from about 20/100,000 (NEAS) to 115/100,000 (LAS) (mean 57.9/100,000; median 55.4/100,000), and the area coverage ranged from about 0.1/km^2 (NEAS) to 7.9/km^2 (LAS) (mean 0.25/km^2; median 0.28/km^2).

Neighbourhood characteristics of automated external defibrillator locations

Neighbourhood characteristics of all AED locations in the country are given in *Table 7* compared to the national LSOA average. Across the country, AEDs are in areas with low residential population density, but high workday/workplace population density. These areas are predominantly white, with low black and Asian populations. They are also areas with a larger population in management/professional and intermediate occupations and a smaller population in routine/

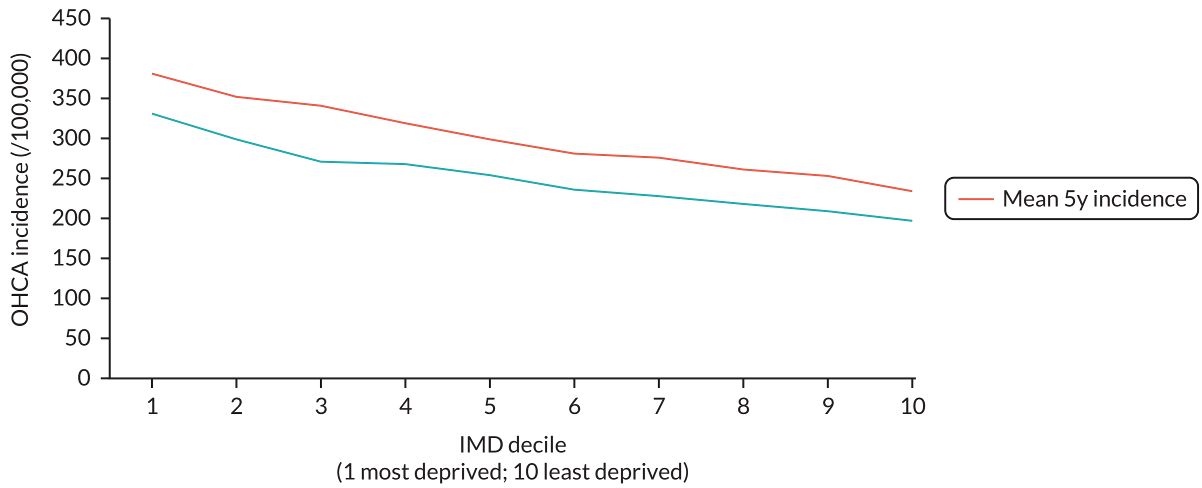

FIGURE 3 Lower-level super output area OHCA incidence by IMD decile.

TABLE 5 Logistic regression model for OHCA location in LSOAs

	OR	Z	95% CI
Workday population density	1.006	0.000	1.004 to 1.008
Proportion of people aged 65 years and over	1.077	0.000	1.068 to 1.086
Proportion of people in mixed ethnic groups	0.907	0.000	0.873 to 0.943
Proportion of people in non-white ethnic groups	1.024	0.000	1.019 to 1.030
Proportion of people in intermediate occupations	0.906	0.000	0.895 to 0.917
Proportion of people unemployed	0.958	0.000	0.951 to 0.966
IMD (decile)	0.861	0.000	0.845 to 0.877

OR, odds ratio.

TABLE 6 Number (and density) of AEDs registered with English ambulance service (as of end of 2019)

Service	Number of AEDs registered[a]	AEDs registered per 100,000	AEDs per km^2
EEAS	2391 (0)	38.6	0.12
EMAS	5891 (8)	114.7	0.35
IOWAS	159 (0)	112.3	0.42
LAS	4750 (40)	52.9	7.85
NEAS	536 (1)	20.2	0.06
NWAS	3914 (5)	53.7	0.28
SCAS	2542 (36)	59.8	0.28
SECAmb	3306 (0)	69.7	0.36
SWAST	3103 (1)	55.4	0.13
WMAS	4464 (7)	77.0	0.34
YAS	1435 (0)	28.0	0.09
Total	32,491 (98)	57.9	0.25

a Number in bracket indicates number of AEDs for which exact fixed location could not be identified.

manual occupations and unemployed. These areas are also more affluent with a low degree of deprivation, as indicated by the proportion of households with no and two or three areas of deprivation, and the mean IMD rank and decile.

Table 7 also compares the characteristics of LSOAs that have an AED with those that do not. Like the findings above, an AED was more likely to be found in an area with a lower residential population density and higher working population density. Automated external defibrillators were also more likely to be found in areas with a lower workday population, but there was just 1.6% points difference. Again, AEDs were significantly more likely to be found in areas with a higher percentage of white population and lower proportion of mixed race, Asian or black population. Areas with significantly more management/professional and intermediate socioeconomic classification occupations (SEC) were also more likely to have an AED, whereas areas with a greater routine/manual SEC were less likely. Areas with an AED were also less likely to be deprived, as shown by the proportion of households with no, or one, measure of deprivation and the IMD decile.

TABLE 7 Comparison of neighbourhood characteristics of AED locations with the national LSOA average, and in LSOAs where AED was present/absent

	AED locations (*n* = 32,393)		National LSOA average (*n* = 32,844)		AED present in LSOA (*n* = 14,277)	AED absent in LSOA (*n* = 18,567)
Characteristic	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Mean (SD)**
Population density (N/hectare)						
Residential	27.5 (36.7)*	15.4 (1.4–39.1)	42.6 (42.3)	34.5 (12.3–57.3)	33.1 (40.8)*	50.0 (41.9)
Workday	55.5 (146.7)*	19.1 (1.4–48.2)	38.6 (53.1)	28.7 (10.8–47.0)	37.6 (69.8)**	39.4 (35.2)
Workplace	41.2 (142.0)*	6.8 (0.6–25.1)	16.1 (42.2)	7.2 (2.9–16.2)	20.4 (59.8)*	12.8 (19.5)
Age group (%)						
< 65	81.9 (7.6)	81.9 (77.1–87.4)	83.4 (7.2)	83.9 (78.8–88.7)	82.2 (7.4)*	84.3 (6.9)
≥ 65	18.1 (7.6)	18.2 (12.8–22.9)	16.6 (7.2)	16.1 (11.3–21.1)	17.8 (7.4)	15.7 (6.9)
Ethnic group (%)						
White	88.4 (16.8)*	96.3 (86.6–98.2)	86.2 (18.7)	94.8 (83.3–97.7)	87.7 (17.7)*	85.1 (19.4)
Mixed	2.0 (1.8)*	1.3 (0.7–2.6)	2.2 (1.9)	1.5 (0.9–2.9)	2.1 (1.9)*	2.3 (1.9)
Non-white	9.6 (15.4	2.4 (1.0–10.4)	11.6 (17.5)	3.6 (1.3–13.4)	10.2 (16.3)*	12.6 (18.2)
Socioeconomic classification						
Management/professional	34.2 (12.1)*	34.4 (25.5–42.4)	31.3 (12.2)	30.5 (21.9–39.8)	33.6 (11.9)*	29.5 (12.2)
Intermediate	29.6 (6.3)*	30.7 (26.5–33.8)	29.4 (5.5)	30.2 (26.2–33.2)	29.8 (5.7)*	29.0 (5.4)
Routine/manual	23.0 (9.8)*	21.6 (15.9–29.4)	25.4 (10.1)	24.6 (17.6–32.6)	23.6 (9.6)*	26.7 (10.3)
Unemployed/not classified	13.1 (10.1)*	9.6 (7.8–14.2)	14.0 (9.2)	10.8 (8.4–16.2)	12.9 (9.2)	14.7 (9.2)
Not living as a couple	41.1 (11.6)**	38.0 (31.7–48.5)	42.2 (10.8)	40.4 (31.3–46.7)	40.7 (10.9)*	43.1 (10.5)
Education, A-level and above	48.0 (13.7)	47.0 (38.6–54.8)	44.8 (13.7)	43.3 (34.9–52.9)	46.8 (13.1)	43.2 (13.9)
Long-term health limits day-to-day activity a lot	8.1 (3.4)	7.6 (5.7–10.0)	8.4 (3.5)	7.9 (5.9–10.4)	8.1 (3.3)	8.6 (3.6)

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TABLE 7 Comparison of neighbourhood characteristics of AED locations with the national LSOA average, and in LSOAs where AED was present/absent (*continued*)

	AED locations (*n* = 32,393)		National LSOA average (*n* = 32,844)		AED present in LSOA (*n* = 14,277)	AED absent in LSOA (*n* = 18,567)
Characteristic	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Mean (SD)**
No. of dimensions households are deprived						
None	44.6 (11.4)*	45.9 (36.6–53.2)	42.7 (12.2)	43.4 (33.5–51.9)	44.3 (11.7)*	41.4 (12.5)
1	32.9 (4.0)*	32.6 (30.4–35.0)	32.6 (3.7)	32.6 (30.4–34.9)	32.7 (3.8)	32.6 (3.7)
2	17.7 (6.5)*	16.8 (12.7–22.1)	19.1 (7.0)	18.5 (13.6–24.2)	18.0 (6.7)*	19.9 (7.2)
3	4.4 (3.4)*	3.3 (1.9–5.8)	5.1 (3.8)	4.0 (2.1–7.2)	4.5 (3.4)*	5.5 (3.9)
4	0.5 (0.6)	0.2 (0.0–0.6)	0.5 (0.6)	0.3 (0.1–0.7)	0.5 (0.6)*	0.5 (0.6)
IMD						
Rank	17,417 (8609)*	17,831 (10,818–24,363)	16,423 (9481)	16,423 (8212–24,634)	17,680 (8924)*	15,456 (9779)
Decile	5.8 (2.6)*	6.0 (4.0–8.0)	5.5 (2.9)	5.5 (3.0–8.0)	5.9 (2.7)*	5.2 (3.0)

* $p < 0.001$, ** $p < 0.01$.

Out-of-hospital cardiac arrest locations, compared to AED locations, had a significantly greater residential population density but lower workday and working population density. Out-of-hospital cardiac arrest locations had a significantly lower white population, but a greater mixed race, Asian and black population. There were fewer people in the management and professional occupational group, and more in other groups. Out-of-hospital cardiac arrest locations were also significantly more deprived than AED locations (lower IMD rank and decile and greater proportion of households deprived in > 1 dimension).

The most deprived LSOAs (IMD deciles 1/2) had the lowest coverage with registered AEDs; 31.0% (2035/6568) contained a device (see *Figure 4*). The highest AED coverage was observed in deciles 6 (50.7%) and 7 (50.5%).

A significant majority of the registered AEDs were in urban areas (63.8%; $p < 0.001$) compared to rural areas (36.2%) (*Table 8*).[74] Figures varied significantly around the country, with the proportion in urban areas ranging from 31.0% in the South-West to 99.5% in London. However, a greater proportion of rural LSOAs (76.9%; $p < 0.001$) had an AED compared to urban areas (36.6%), the proportion increasing with degree of rurality. Excluding London as a special situation, the proportion of AEDs that were in rural areas increased the further south one went (North 30.3%; Midlands 43.7%; South 48.7%).

It was planned to use information collected by The Circuit, the national defibrillator database. However, the COVID-19 pandemic and subsequent lockdowns prevented BHF from incorporating ambulance AED databases and rolling out promotion to encourage people to register AEDs on the database. The Circuit has only recently brought on board the last ambulance service. We were, therefore, unable to incorporate these data into the analysis. Nevertheless, as of June 2022 there were 33,689 AEDs registered with The Circuit in England that had been claimed/registered by their guardians. An analysis of the neighbourhood characteristics of their locations was carried out and found to be no different from the analysis in this report and published by Brown *et al.*[74] AEDs were in LSOAs that statistically had a lower residential but higher workplace population density, and had people predominantly from a white ethnic background and working in higher socioeconomically classified occupations (see *Appendix 5*). The LSOAs were also more affluent, that is, higher IMD decile.

Regional variation

The neighbourhood characteristics of where AEDs are in each ambulance service region compared to the regional average are given in *Appendix 6*.

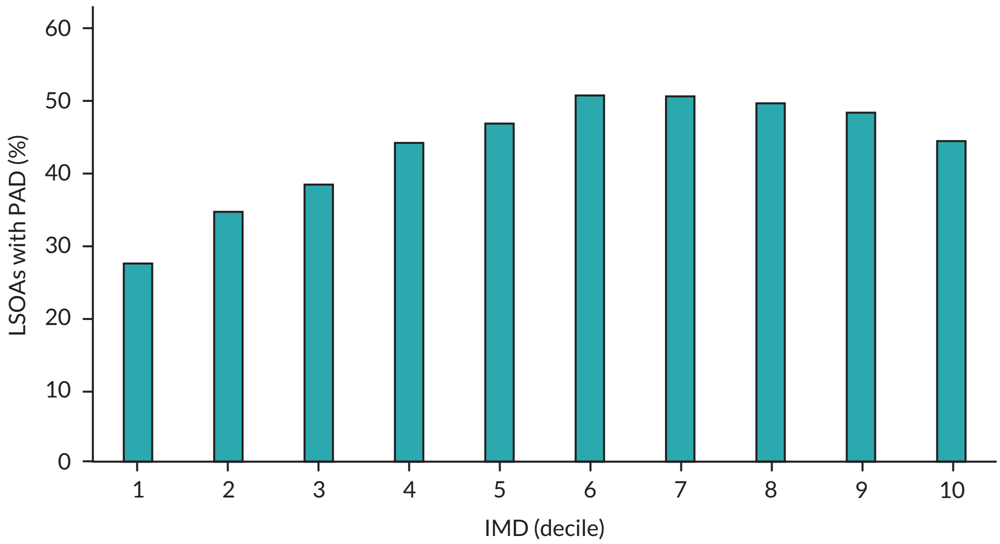

FIGURE 4 The percentage of LSOAs within each deprivation decile that contain a publicly accessible AED (1 = most deprived, 10 = least deprived).

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TABLE 8 Distribution of registered AEDs by RUC of the LSOA

	AEDs	LSOAs		
RUC	Number (proportion of total, %)	Number (%) with an AED	Number (%) without an AED	Proportion (%) of RUC LSOAs with an AED
Urban	20,657 (63.8)	9972 (69.8)	17,274 (93.0)	36.6
Major conurbation	8547 (26.4)	4153 (29.1)	7370 (39.7)	36.0
Minor conurbation	806 (2.5)	359 (2.5)	849 (4.6)	29.7
City and town	11,218 (34.6)	5424 (38.0)	9032 (48.6)	37.5
City and town, sparse	86 (0.3)	36 (0.2)	23 (0.1)	61.0
Rural	11,736 (36.2)	4305	1293	76.9
Town and fringe	4338 (13.4)	1948 (13.6)	989 (5.3)	66.3
Town and fringe, sparse	243 (0.7)	94 (0.7)	25 (0.1)	79.0
Rural village and dispersed	6483 (20.0)	2091 (14.6)	270 (1.5)	88.6
Rural village and dispersed, sparse	672 (2.1)	172 (1.2)	9 (< 0.1)	95.0
Region[a]				
North	6200 (19.1)	2842 (19.9)	6629 (35.7)	30.0
Midlands	12,444 (38.4)	4976 (34.8)	4900 (26.4)	50.4
South	13,749 (42.4)	6459 (45.2)	7038 (37.9)	47.9

a North: North-East, North-West, Yorkshire; Midlands: East of England, East Midlands, West Midlands; South: South-West, South Central, South-East Coast, London, Isle of Wight.

In summary:

- Residential population density: in all ambulance service regions AEDs were in areas with a lower residential population density compared to the regional average.
- Workday population density: in general AEDs were in LSOAs with a lower workday population density than the regional average, except for LAS and NWAS.
- Workplace population density: this mimicked the pattern for workday population density.
- Proportion of the population aged over 65 years: in general, the proportion was lower in LSOAs with an AED, except for NWAS, where the proportions are equivocal, and LAS, where it was greater.
- Proportion of population in different ethnic groups: in all ambulance services, AEDs were in areas with a greater proportion of people indicating they were from a white ethnic background compared to the regional average, but a lower proportion of non-white ethnic background.
- National statistics SEC: in NEAS, SCAS, SWAST, WMAS and YAS, AEDs were in areas with a higher proportion of individuals in managerial, professional and intermediate occupations, and a lower proportion of individuals in routine and manual occupations, and unemployed, compared to the regional average. In the other services, there was no difference.
- Proportion of households with dimensions of deprivation: AEDs were in areas where the proportion of households with no deprivation or deprived in one dimension was higher than the regional average, but not in areas where households were deprived in two or more dimensions.
- IMD: on the basis of the IMD, AEDs appeared to be placed in areas that were more affluent than the regional average, that is, IMD rank and decile higher.

Automated external defibrillator logistic regression analysis

Bivariate logistic regression analysis for AED location indicated that all variables were statistically significantly related to whether an AED was in a LSOA or not (see *Appendix 7*). The odds increased with workplace population density, the proportion of people aged 65 years and over, the proportion of people in a white ethnic group, proportion of people in management, professional and intermediate occupations, and greater degrees of affluence (i.e. lower levels of deprivation). Backwards stepwise analysis of the data and taking a *p*-value of 0.05 as significant resulted in the final model given *Table 9*, after checking for collinearity between variables. The model indicates that AEDs are significantly less likely to be in areas with a low residential population density and more likely to be in areas with a higher working population density. Similarly, they are more likely to be in areas with a greater proportion of people aged 65 years and over, and areas where there is a greater proportion of people in higher SECs. The odds of a LSOA containing an AED also decreased with increasing IMD decile, that is, decreasing deprivation, and after controlling for all the other variables in the model.

TABLE 9 Logistic regression model for AED placement in LSOAs

	OR	*p*-value	95% CI
Residential population density (*n*/hectare)	0.983	0.000	0.982 to 0.983
Working population density (*n*/hectare)	1.023	0.000	1.021 to 1.025
Proportion of people aged 65 years and older (%)	1.056	0.000	1.050 to 1.062
Proportion of mixed ethnic background (%)	1.030	0.000	1.011 to 1.048
Proportion of people in management and professional occupations (%)	1.016	0.000	1.012 to 1.020
Proportion of people in routine and manual occupations (%)	0.980	0.000	0.975 to 0.985
Long-term health limits day-to-day activity a lot	0.913	0.000	0.901 to 0.925
IMD (decile)	0.858	0.000	0.843 to 0.873

OR, odds ratio.

Out-of-hospital cardiac arrest coverage

Euclidean (straight-line) distances between out-of-hospital cardiac arrests and automated external defibrillators

The mean number of OHCAs that occurred in all LSOAs was 4.5 (SD 3.9) and in LSOAs where an OHCA had occurred the average number was 4.8 (SD 3.9). The maximum number of OHCAs occurring in any given LSOA was 116 (median 4; IQR 2–6). The average number of AEDs in all LSOAs was 1.0 (SD 1.9) and in only those LSOAs with an AED it was 2.3 (SD 2.4). The maximum number of AEDs in any given LSOA was 119 (median 2; IQR 1–3). The correlation between OHCA number and AED number was $r = 0.148$ ($p < 0.001$) ($r = 0.194$ where an OHCA had occurred and an AED was located).

There were 2135 LSOAs where no OHCA occurred and 18,567 where no AED was located. There were 1271 LSOAs in which no OHCA occurred, and no AED was located; 17,296 where an OHCA occurred but no AED was located; 864 where no OHCA occurred but an AED was located; and 13,413 where an OHCA occurred and an AED was located. The mean IMD decile in these four groups was 6.47, 5.12, 6.78 and 5.82, respectively; each mean was significantly different from all the others ($p < 0.01$).

Table 10 shows the variation in the mean and median Euclidean (straight-line) distance between an OHCA and the nearest known registered AED. The overall mean was 734 m (SD 2350 m) and the median was 425 m (IQR 222–810 m). The mean distance varied significantly between services, ranging from 295 m in LAS to 1537 m in SCAS, and the median ranged from 247 m in LAS (IQR 135–398 m) to 1022 m in NEAS (IQR 518–1713 m).

Table 11 shows the number of OHCAs in each service region and the number of these events that occurred within specified distances of an AED. A total of 12,392 (8.4%) of those cases we were able to geocode were identified to have occurred within 100 m of a registered AED; 21,870 (14.9%) cases out of a total of 147,278 were identified to have occurred within 150 m and an additional 30,422 (20.6%) between 150 and 300 m. In total, 80.2% of all OHCAs occurred within 1 km of an AED. These numbers were highly variable between services. For example, only 4.8% of NEAS and 5.3% of EEAS OHCAs occurred within 150 m of a registered AED in their region. However, in WMAS and LAS the corresponding figure was 17.6% and 28.0%, respectively.

TABLE 10 Mean, SD and median Euclidean distance (metres) between an OHCA and nearest AED in England

Service	Mean (SD)	95% CI	Median (IQR)
EEAS	987 (2599)	916 to 1058	670 (353–1246)
EMAS	675 (4541)	593 to 758	342 (199–537)
IOWAS	398 (420)	337 to 460	263 (172–434)
LAS	295 (315)	292 to 299	247 (135–398)
NEAS	1265 (3228)	1206 to 1325	1022 (518–1713)
NWAS	1181 (2169)	1152 to 1210	568 (274–1518)
SCAS	609 (1825)	569 to 649	452 (252–743)
SECAmb	523 (1546)	497 to 549	382 (206–660)
SWAST	801 (3457)	750 to 852	561 (293–967)
WMAS	464 (524)	457 to 471	365 (201–591)
YAS	1140 (1535)	1109 to 1171	852 (414–1572)
All	734 (2350)	723 to 747	425 (222–810)

TABLE 11 Number (%) of OHCA where an AED is located within specified distances in ambulance service

Service	Number (%) of OHCAs occurring within specified distance of an AED				
	≤ 100 m (%)	≤ 150 m (%)	≤ 300 m (%)	≤ 500 m (%)	≤ 1000 m (%)
EEAS	124 (2.4)	276 (5.3)	1036 (19.9)	1973 (37.9)	3478 (66.8)
EMAS	1146 (9.8)	1922 (16.5)	5018 (43.0)	8256 (70.8)	10,893 (93.4)
IOWAS	16 (8.8)	35 (19.2)	102 (56.0)	145 (79.7)	169 (92.9)
LAS	4197 (16.0)	7363 (28.1)	15,767 (60.1)	22,351 (85.2)	25,980 (99.0)
NEAS	273 (2.4)	538 (4.7)	1434 (12.7)	2699 (23.8)	5569 (49.2)
NWAS	1261 (5.7)	2435 (11.1)	6063 (27.6)	10,036 (45.6)	14,511 (66.0)
SCAS	444 (5.6)	866 (11.0)	2499 (31.7)	4337 (55.0)	6772 (85.9)
SECAmb	1248 (9.4)	2183 (16.5)	5221 (39.3)	8312 (62.6)	11,847 (89.3)
SWAST	924 (5.3)	1743 (9.9)	4513 (25.7)	7905 (45.1)	13,375 (76.3)
WMAS	2447 (10.9)	3930 (17.5)	9060 (40.4)	14,924 (66.5)	20,881 (93.0)
YAS	312 (3.3)	579 (6.1)	1577 (16.5)	2931 (30.7)	5409 (56.7)
Total	12,392 (8.4)	21,870 (14.9)	52,290 (35.5)	83,869 (56.7)	118,884 (80.2)

Real-life (walking) distance between out-of-hospital cardiac arrests and automated external defibrillators

Various studies have indicated that a straight-line (Euclidean) distance between a public-access AED and OHCA would underestimate travel distance in the real world.[144,145] We therefore calculated the 'real-world' travel distance that considered roads and footpaths. The mean 'real-life' distance was 1014 m (SD 2835), with a mean service range of 449 m in LAS to 1695 m in NEAS (*Table 12*). The median distance was 638 m (IQR 347–1142 m), and the median range was 384 m in LAS to 1388 m in NEAS. The number of OHCAs that occurred within 100 m real-life distance was 7965 (5.4%), which increased to 57,225 (38.9%) within 500 m (*Table 13*).

Comparison of Euclidean and real-world numbers

Table 14 compares the number of OHCAs that occurred within specified distances: straight-line versus real-life in each ambulance service; distances for the latter were significantly lower ($p < 0.0001$). Using real-world travel estimates, the number of OHCAs within 100 m of an AED reduced from 8.4% to 5.4%, and within 500 m from 56.7% to 38.9%. Overall, real-life numbers are approximately 60% of the Euclidean numbers (64% for ≤ 100 m; 68% for ≤ 500 m; 87% for ≤ 1000 m). For numbers within 100 m the proportion ranged from 60% in EEAS to 81% in IOWAS.

Within each calculation of Euclidean and real-world travelling distances the identity of the nearest AED may not change, but in other instances the identity did change. For 118,528 (80.5%) OHCAs the AED identity did not change, whereas in 28,750 (19.5%) the identity did change (*Table 15*). For OHCA cases where the nearest AED did not change there was a significant increase in the distance needed to walk of about 245.5 m (median 172.1; IQR 71.3–329.1). For OHCAs where the AED identity changed there was also a significant increase in mean distance of about 377.1 m (median 266.2; IQR 137.8–477.3).

The median ratio of real-world to Euclidean distance was 1.36 (IQR 1.20–1.63) (*Table 16*). For a bystander at an OHCA this would mean an extra walking distance of 188.5 m (median) (IQR 80.6–357.5 m), that is, about 94 m there and back. A similar ratio was seen when looking at the Utstein location of the OHCA event. On average, the true-route distance was about 173 m for OHCAs occurring in a public place, 196 m for those occurring in a residential location and 156 m for those occurring in assisted living accommodation. In urban areas the increase in distance was significantly different between major (168 m) and minor (232 m) conurbations. Similar differences were seen in rural areas: in rural town and fringe areas the increase was about 192 m, and in rural village and dispersed it was about 268 m.

TABLE 12 Mean, SD and median real-world travelling distance (metres) between an OHCA and nearest AED in England

Service	Mean (SD)	95% CI	Median (IQR)
EEAS	1356 (3062)	1273 to 1440	969 (541–1682)
EMAS	936 (5727)	832 to 1040	525 (307–798)
IOWAS	580 (610)	491 to 669	399 (227–722)
LAS	449 (424)	444 to 454	384 (222–608)
NEAS	1695 (3822)	1624 to 1765	1388 (741–2275)
NWAS	1559 (2544)	1526 to 1593	821 (414–2001)
SCAS	867 (2142)	820 to 914	672 (396–10,65)
SECAmb	761 (1868)	729 to 793	590 (322–957)
SWAST	1110 (4035)	1050 to 1169	815 (451–1333)
WMAS	677 (725)	668 to 686	554 (314–859)
YAS	1513 (1859)	1476 to 1551	1158 (613–2046)
All	1014 (2835)	1000 to 1029	638 (347–1142)

TABLE 13 Number (%) of OHCAs where an AED is located within specified distances in ambulance service

Service	Number (%) of OHCAs occurring within specified distance of an AED				
	≤ 100 m	≤ 150 m	≤ 300 m	≤ 500 m	≤ 1000 m
EEAS	74 (1.4)	146 (2.8)	469 (9.0)	1140 (21.9)	2672 (51.4)
EMAS	874 (7.5)	1210 (10.4)	2811 (24.1)	5547 (47.6)	9955 (85.3)
IOWAS	13 (7.1)	20 (11.0)	66 (36.3)	114 (62.6)	162 (89.0)
LAS	2406 (9.2)	3875 (14.8)	9779 (37.3)	16,750 (63.8)	24,890 (94.9)
NEAS	166 (1.5)	271 (2.4)	799 (7.1)	1705 (15.0)	4039 (25.6)
NWAS	735 (3.3)	1246 (5.7)	3558 (16.2)	6875 (31.3)	12,472 (56.7)
SCAS	268 (3.4)	435 (5.5)	1314 (16.7)	2750 (34.9)	5698 (72.3)
SECAmb	798 (6.0)	1233 (9.3)	3004 (22.6)	5583 (42.1)	10,199 (76.9)
SWAST	593 (3.4)	960 (5.5)	2450 (14.0)	4987 (28.4)	10,672 (60.9)
WMAS	1828 (8.1)	2396 (10.7)	5302 (23.6)	9986 (44.5)	18,460 (82.2)
YAS	210 (2.2)	331 (3.5)	883 (9.3)	1788 (18.7)	4145 (43.5)
Total	7965 (5.4)	12,123 (8.2)	30,435 (20.7)	57,225 (38.9)	103,364 (70.2)

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TABLE 14 Proximity (Euclidean and real-world distance) of OHCAs to public-access AEDs in each ambulance service (number and percentage)

Distance between OHCA and AED (m)	Euclidean distance (%)	Real-world travel distance	Euclidean distance (%)	Real-world travel distance
	EEAS		EMAS	
≤ 100	124 (2.4)	74 (1.4)	1146 (9.8)	874 (7.5)
≤ 500	1973 (37.9)	1140 (21.9)	8256 (70.8)	5547 (47.6)
≤ 1000	3478 (66.8)	2672 (51.4)	10,893 (93.4)	9955 (85.3)
	IOWAS		*LAS*	
≤ 100	16 (8.8)	13 (7.1)	4197 (16.0)	2406 (9.2)
≤ 500	145 (79.7)	114 (62.6)	22,351 (85.2)	16,750 (63.8)
≤ 1000	169 (92.9)	162 (89.0)	25,980 (99.0)	24,890 (94.9)
	NEAS		NWAS	
≤ 100	273 (2.4)	166 (1.5)	1261 (5.7)	735 (3.3)
≤ 500	2699 (23.8)	1705 (15.0)	10,036 (45.6)	6875 (31.3)
≤ 1000	5569 (49.2)	4039 (25.6)	14,511 (66.0)	12,472 (56.7)
	SCAS		*SECAmb*	
≤ 100	444 (5.6)	268 (3.4)	1248 (9.4)	798 (6.0)
≤ 500	4337 (55.0)	2750 (34.9)	8312 (62.6)	5583 (42.1)
≤ 1000	6772 (85.9)	5698 (72.3)	11,847 (89.3)	10,199 (76.9)
	SWAST		*WMAS*	
≤ 100	924 (5.3)	593 (3.4)	2447 (10.9)	1828 (8.1)
≤ 500	7905 (45.1)	4987 (28.4)	14,924 (66.5)	9986 (44.5)
≤ 1000	13,375 (76.3)	10,672 (60.9)	20,881 (93.0)	18,460 (82.2)
	YAS		***Total***	
≤ 100	312 (3.3)	210 (2.2)	12,392 (8.4)	7965 (5.4)
≤ 500	2931 (30.7)	1788 (18.7)	83,869 (56.7)	57,225 (38.9)
≤ 1000	5409 (56.7)	4145 (43.5)	118,884 (80.2)	103,364 (70.2)

TABLE 15 Change in distance travelled if the nearest AED did not change between Euclidean and real-world travelling distance calculations

Service	AED change					
	No			Yes		
	N (%)	Mean (SD)	Median (IQR)	*N* (%)	Mean (SD)	Median (IQR)
EEAS	4459 (85.7)	323.2 (340.6)	236.2 (118.5–407.6)	743 (14.3)	607.1 (544.6)	445.7 (266.8–771.5)
EMAS	9157 (78.5)	170.2 (201.2)	123.8 (45.7–231.2)	2508 (21.5)	344.5 (388.5)	251.1 (144.9–414.7)
IOWAS	155 (85.2)	154.3 (176.8)	111.0 (32.2–200.6)	27 (14.8)	342.5 (382.3)	247.5 (108.2–416.5)
LAS	19,502 (74.3)	147.3 (295.2)	108.9 (22.3–235.3)	6734 (25.7)	171.3 (317.2)	155.8 (45.5–299.1)
NEAS	9685 (85.5)	373.3 (313.8)	295.1 (157.5–505.6)	1645 (14.5)	707.9 (539.8)	557.0 (308.4–977.9)
NWAS	17,867 (81.3)	345.3 (414.4)	212.4 (93.9–438.6)	4120 (18.7)	483.1 (539.9)	301.2 (152.5–613.0)
SCAS	6262 (79.4)	220.0 (218.7)	171.4 (81.0–289.8)	1624 (20.6)	385.3 (349.9)	297.2 (173.4–474.6)
SECAmb	10,376 (78.2)	202.9 (216.1)	149.1 (61.5–280.6)	2894 (21.8)	352.3 (341.3)	262.1 (144.0–440.9)
SWAST	14,913 (85.0)	264.0 (266.1)	201.6 (93.5–348.9)	2624 (15.0)	498.7 (516.8)	357.9 (210.7–615.0)
WMAS	17,786 (79.3)	180.4 (202.3)	135.9 (54.9–247.3)	4658 (20.7)	328.0 (322.2)	254.5 (151.9–407.7)
YAS	8366 (87.7)	333.5 (326.9)	261.8 (133.6–441.2)	1173 (12.3)	621.9 (604.5)	451.2 (250.1–809.5)
Total	118,528 (80.5)	245.5 (302.5)	172.1 (71.3–329.1)	28,750 (19.5)	377.1 (448.4)	266.2 (137.8–477.3)

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TABLE 16 'Straight-line' distance from OHCAs to the closest accessible AED and the corresponding 'true route' distance in different Utstein locations and RUC

		Utstein location			RUC				
	Total	Public	Residential	Assisted living	Urban major conurbation	Urban minor conurbation	Urban city and town	Rural town and fringe	Rural village and dispersed
'Straight-line' distance to the closest AED (m), median (IQR)	425.0 (222.4–810.3)	453.3 (181.9–963.0)	456.2 (255.2–827.2)	398.4 (170.7–799.0)	357.0 (189.6–645.4)	564.7 (303.3–1335.3)	477.6 (256.7–838.8)	398.2 (208.8–859.5)	767.7 (274.5–1770.2)
'True-route' distance to the closest AED (m), median (IQR)	637.8 (346.5–1141.5)	660.0 (280.7–1330.6)	682.8 (394.5–1159.5)	581.0 (280.7–1094.8)	542.5 (298.2–933.9)	819.1 (457.8–1728.9)	706.9 (397.4–1171.7)	626.4 (336.7–1232.7)	1078.6 (400.5–2457.8)
Ratio, median (IQR)	1.36 (1.20–1.63)	1.33 (1.17–1.58)	1.36 (1.21–1.61)	1.31 (1.15–1.57)	1.4 (1.2–1.7)	1.3 (1.2–1.5)	1.4 (1.2–1.6)	1.4 (1.2–1.7)	1.3 (1.1–1.6)
Absolute difference (m), median (IQR)	188.5 (80.6–357.5)	173.2 (61.8–364.2)	196.1 (92.0–355.8)	155.5 (58.2–314.7)	167.5 (65.7–328.5)	232.3 (112.4–409.5)	197.8 (95.9–350.7)	192.3 (75.7–394.8)	268.2 (69.7–629.7)

Table 17 shows the availability of publicly accessible AEDs and whether an AED was used on an OHCA patient prior to the arrival of EMS, according to the OHCAO registry. The number of AEDs used is lower than the number that was available at the time of the OHCA. However, it may be that even though an AED was available it was deemed not necessary to get it for a specific reason that we do not know about. Also, data quality for AED availability and use within the OHCAO registry is variable, and for some services very poor. There were also circumstances where it was indicated that AED availability was 'No' or 'Unknown', and yet an AED was used.

For those OHCAs where an AED was used Table 18 shows the distance to the nearest AED according to the database held at each ambulance service. The numbers indicate that in about 46% of cases the nearest AED, according to the ambulance service database, was more than 500 m (walking distance) away from the incident, that is, outside the AED operational radii for the services. This could indicate that a significant number of those that could have been used were not registered with ambulance services.

Table 19 indicates the number of OHCAs within specified distances where an AED was indicated as unavailable, or the availability was unknown. In a significant number of OHCAs an AED was available, that is, within 500 m of the location according to the ambulance service databases. Thus, either the services deemed it not necessary to send someone to get the nearest AED or they were not using the database to its full potential.

Relative coverage loss

It was not possible to calculate the relative coverage loss because accessibility information for AEDs was insufficient or lacking. However, if we consider when the OHCA occurred, that is, hour of the day and day of the week, we could assess the actual coverage if we assumed that if an OHCA occurred at the weekend or outside of 'normal' working hours during the week, then any AED was not available. We also randomly selected AEDs in the whole data set, so they were unavailable. According to Deakin *et al.*,[54] in their assessment of availability in SCAS, all AEDs were available during the daytime but only 34.3% at night. In addition, they observed that in 66% of OHCAs that occurred out of hours, where if they had occurred during working hours an AED was available, the AED was not available. We therefore assessed the potential 'real-life' availability of AEDs based on this figure of 66%. A total of 96,436 (65.5%) of OHCAs occurred out of hours, that is, not during normal working hours. Out of hours was assumed to be the weekend (Saturday/Sunday) and between the hours of 18.00 and 08.00 during the week (Monday–Friday). The proportion of OHCAs that occurred out of hours for each operating distance (≤ 100 m, ≤ 150 m, etc.) was similar. Table 20 shows number of OHCAs that occurred within working hours and out of hours by the distance to the nearest AED. If we assume these numbers indicate the 'Actual coverage' and numbers in Table 13 indicate the 'Assumed coverage' we estimate that the relative coverage loss is about 41–44%.

The key OHCA characteristics and resuscitation status according to distance (≤ 100, 101–250, 251–500, > 500) to the nearest AED are presented in Table 21. The median distance to the nearest AED was 638 m (IQR 347–1141 m), and 26.5% (*n* = 39,059) of cardiac arrests were confirmed to have occurred in a residential location, and overall 3.3% were defibrillated by a bystander. Out-of-hospital cardiac arrest cases with a shorter distance to nearest AED were more often male (64.6%), were more often witnessed by a bystander (48.9%) and received more bystander intervention:

TABLE 17 Number of OHCAs within the OHCAO registry where a publicly accessible AED was indicated as available for use and where one was used according to ambulance services

	AED use (*N*)			
AED availability	**No AED used**	**AED used**	**Unknown whether AED used**	**Total**
AED not available	30,742	557	12	31,311
AED available	1125	1645	35	2805
AED availability unknown	69,691	2627	40,844	113,162
Total	101,558	4829	40,891	147,278

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TABLE 18 Euclidean and walking distance to the nearest AED for OHCAs in which ambulance services indicated a PAD was used (n = 4829)

	Euclidean distance			Walking distance		
Distance (m)	**Number**	**Percentage**	**Cumulative percentage**	**Number**	**Percentage**	**Cumulative percentage**
≤ 100	1339	27.7	27.7	926	19.2	19.2
100–150	449	9.3	37.0	239	4.9	24.1
150–300	845	17.5	54.5	730	15.1	39.2
300–500	685	14.2	68.7	731	15.2	54.4
500–1000	667	13.8	82.5	1022	21.2	75.6

TABLE 19 Euclidean and walking distance to the nearest AED for OHCAs in which ambulance services indicated an AED was unavailable or the availability was unknown (n = 144,473)

	Euclidean distance			Walking distance		
Distance (m)	**Number**	**Percentage**	**Cumulative percentage**	**Number**	**Percentage**	**Cumulative percentage**
≤ 100	7160	5.0	5.0	11,421	7.9	7.9
100–150	4034	2.8	7.8	9288	6.4	14.3
150–300	17,976	12.4	20.2	30,022	20.8	35.1
300–500	26,465	18.3	38.5	31,270	21.6	56.7
500–1000	45,703	31.6	70.1	34,660	24.0	80.7

TABLE 20 Number and percentage of OHCAs occurring within specified distances and whether the event occurred during working hours or out of hours

Distance (m)	Working-hour OHCAs (a)	Out-of-hours OHCAs			*N* (%) (a + c)	Coverage loss (%)
		Total	Available (34% of total) (c)	Unavailable (66% of total)		
≤ 100	2937	5021	1707	3314	4644 (3.2)	41.6
100–150	1429	2726	927	1799	2356 (1.6)	43.3
150–300	6359	11,924	4054	7870	10,413 (7.1)	43.0
300–500	8965	17,773	6043	11,730	15,008 (10.2)	43.9
500–1000	15,663	30,414	10,341	20,073	26,004 (17.7)	43.6
> 1000	15,489	28,578	9717	18,861	25,206 (17.1)	42.8

Note
Out of hours defined as the weekend (Saturday/Sunday) and between 18.00 and 08.00 during weekdays (Monday–Friday).

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TABLE 21 Cardiac-arrest-related characteristics in OHCAs according to distance to nearest AED

	Distance from cardiac arrest to nearest AED in metres					
	≤ 100	101–250	251–500	> 500	All	Missing data
Number (%)	7958	15,690	33,486	89,913	147,278	0
Distance to nearest AED in metres, median (IQR)	32 (0.6–71)	185 (148–218)	372 (312–434)	980 (695–1638)	638 (347–1141)	0
Age, median (IQR)	71 (56–82)	70 (55–81)	71 (56–82)	71 (57–81)	71 (57–81)	4886
Men, no. (%)	5139 (64.6)	9820 (62.6)	20,811 (62.2)	54,739 (60.7)	90,509 (61.5)	5152
Bystander-witnessed, no. (%)	3894 (48.9)	7366 (47.0)	15,041 (44.9)	39,055 (43.3)	65,356 (44.4)	266
Bystander CPR, no. (%)	4950 (62.2)	8684 (55.4)	18,072 (54.0)	41,718 (55.2)	81,424 (55.3)	266
Bystander defibrillation, no. (%)	924 (11.6)	748 (4.8)	948 (2.8)	2209 (2.5)	4829 (3.3)	
Ambulance response time in minutes, median (IQR)	6.5 (3.4–10.1)	6.3 (3.6–9.7)	6.3 (3.5–9.7)	6.5 (3.7–10.0)	6.4 (3.6–9.9)	16,377
OHCA in home, no. (%)	1496 (18.8)	3292 (21.0)	8728 (26.1)	25,543 (28.3)	39,059 (26.5)	
CPR stopped at scene, no. (%)	2870 (36.1)	5892 (37.6)	12,729 (38.0)	31,268 (34.7)	52,759 (35.8)	
Admitted to hospital with ROSC, no. (%)	2468 (31.0)	4563 (29.1)	9417 (28.1)	23,185 (25.7)	39,633 (26.9)	
Admitted to hospital with ongoing CPR, no. (%)	2604 (32.7)	5206 (33.2)	11,283 (33.7)	35,527 (39.4)	54,620 (37.1)	266
Survived to hospital discharge, no. (%)	8957 (10.8)	1484 (9.5)	2763 (8.3)	7057 (7.8)	12,161 (8.3)	266

CPR (62.2%) and defibrillation (11.6%). More cases were admitted to hospital with an ROSC and survived to hospital discharge; fewer were admitted with ongoing CPR.

Among the 7958 patients with an accessible AED within 100 m walking distance, 11.6% (*n* = 924) were bystander-defibrillated before EMS arrival (*Table 22*). These cases also had a significantly greater chance of being witnessed by a bystander and receiving CPR from one. They also had a greater chance of achieving an ROSC at hospital handover (36.4% vs. 30.3%) and surviving to hospital discharge (16.6% vs. 10.0%).

Where we could confirm the Utstein location of the OHCA case, a total of 530 (6.7%) occurred in a public location and 18.9% (*n* = 1496) in a residential location, within 100 m of an AED (*Table 23*). Out-of-hospital cardiac arrest cases that occurred in the home involved significantly older people who were more often female. The likelihood of the cardiac arrest being witnessed by a bystander was reduced significantly, and chances of receiving CPR were lower. Subsequently, bystander defibrillation rates were low in this group, and therefore the chances of achieving an ROSC at hospital handover and surviving to hospital discharge much lower.

Summary of results for work package 1

Cardiac arrests were observed to occur in LSOAs that had a higher residential and workday population density, were more urban, had a larger proportion of workers in routine jobs or unemployment, had a greater proportion of residents identifying their ethnicity as non-white or mixed race, and a greater degree of deprivation.

Automated external defibrillators were placed in more affluent areas with a lower residential and higher workday population density, lower proportions of the population from now-white ethnic groups, and a greater proportion of people in management/professional occupations.

There were 18,567 (56.5%) LSOAs in which no AED was located and 14,277 (43.4%) in which at least one AED was located.

The average Euclidean distance between the OHCA and its nearest AED was 734 m (median 425 m; IQR 222–810 m). Overall, 12,392 (8.4%) of OHCAs occurred within 100 m of an AED (150 m: 14.9%; 300 m: 35.5%; 500 m: 56.7%) if the distance was measured in a straight line.

The average real-world walking distance, which was significantly longer than the Euclidean, was 1014 m (median 638 m; IQR 347–1142 m). Consequently, the number of OHCAs occurring within specified distances was significantly lower: 7965 (5.4%) within 100 m (150 m: 8.2%; 300 m: 20.7%; 500 m: 38.9%)

TABLE 22 Characteristics of OHCA patients with nearest AED within 100 m distance according to bystander defibrillation

	Bystander defibrillation	No bystander defibrillation
Number (%)	924 (11.6)	7039
Distance to nearest AED in metres, median (IQR)	11 (0.1–53)	36 (1–72)
Age, median (IQR)	69 (55–81)	71 (56–82)
Men, no. (%)	672 (72.7)	4467 (63.5)
Bystander-witnessed, no. (%)	648 (70.1)	3246 (46.1)
Bystander CPR, no. (%)	899 (97.3)	4051 (57.6)
Ambulance response time in minutes, median (IQR)	7.2 (4.6–10.9)	6.4 (3.2–9.9)
OHCA in home, no. (%)	47 (5.1)	1449 (20.6)
Admitted to hospital with ROSC, no. (%) ROSC	336 (36.4)	2132 (30.3)
Survived to hospital discharge, no. (%)	153 (16.6)	704 (10.0)

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TABLE 23 Characteristics of OHCA patients according to location of cardiac arrest

	≤ 100 m to nearest AED		> 100 m to nearest AED	
	Home	**Public**	**Home**	**Public**
Number (%)	1496 (18.9)	530 (6.7)	37,563 (27.0)	4376 (3.1)
Distance to nearest AED in metres, median (IQR)	10 (0–68)	17 (0.1–58)	707 (427–1190)	769 (388–1463)
Age, median (IQR)	73 (60–83)	67 (55–77)	72 (59–82)	64 (51–74)
Men, no. (%)	894 (59.8)	439 (82.8)	22,789 (60.7)	3566 (81.5)
Bystander-witnessed, no. (%)	745 (49.8)	381 (71.9)	17,889 (47.6)	2849 (65.1)
Bystander CPR, no. (%)	946 (63.2)	415 (78.3)	21,705 (57.8)	3349 (76.5)
Ambulance response time in minutes, median (IQR)	9.0 (5.4–14.1)	6.1 (3.4–9.8)	7.1 (4.2–11.3)	7.0 (4.2–10.9)
Bystander defibrillation, no. (%)	47 (3.1)	196 (37.0)	399 (1.1)	631 (14.4)
Admitted to hospital with ROSC, no. (%) ROSC	380 (25.4)	236 (44.5)	9927 (26.4)	1623 (37.1)
Survived to hospital discharge, no. (%)	94 (6.3)	109 (20.6)	2407 (6.4)	780 (17.8)

In 118,526 OHCAs the identity of the closest AED did not change, whereas in 28,750 it did.

Real-world distances between OHCAs and nearest AED were significantly shorter in urban areas compared to rural areas (almost half).

In OHCA cases where an AED was indicated as being used, the distance to the nearest registered AED varied significantly, with about 21% further than 500 m. This could indicate that someone had gone to get the AED, or, more likely, an AED that was nearer the OHCA location was used but was not registered with the ambulance service.

In about 57% of cases where an AED was said to not be available, an AED was located within 500 m.

Based on the assumption that in about 66% of OHCAs that occurred out of hours an AED is not available, coverage loss was estimated to be about 40% if AEDs were made available all the time.

Work package 2: alternative-placement strategy coverage

This WP compared the coverage of various deployment strategies (POI/buildings, grid-based) and an optimisation model with current strategies.

Points of interest

The number and proportion of OHCAs covered by each POI are given in the following sections. Tables detailing the coverage information for each ambulance service are in *Appendix 9*. *Table 24* summarises the country-wide situation giving the total numbers of POIs and the number (and percentage) of OHCAs covered:

- ignoring the presence of a current registered AED
- given that OHCAs were not covered by a currently registered AED
- by a currently registered AED or the POI.

The numbers (percentages) of OHCAs 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.

Table 25 shows the assumed and actual coverage numbers for each POI, and coverage loss and efficiency. Data within the table are also shown in *Figures 5–8*.

Figure 5 shows the range of assumed coverage among the POIs, that is, an AED would be accessible 24/7 if deployed at this POI. The highest was seen for cash machines, places of worship and public houses, and the lowest for supermarkets, banks/building societies and state secondary schools. Similarly, there was a significant range of actual coverage (see *Figure 6*), that is, an AED would be accessible only during opening hours of the POI as indicated in *Table 34* (see *Appendix 1*). Ignoring cash machines, care homes and community halls, where we have assumed that AEDs are available 24/7, actual coverage was the highest for places of worship, public houses and leisure centres.

Figure 7 shows the range of coverage loss between assumed and actual coverage, calculated as assumed minus actual divided by assumed. The loss for cash machines, care homes and community halls is zero. The loss was greatest for state schools if we assumed all OHCAs that occurred outside of normal school opening time did not have access to an AED at these locations.

Coverage efficiency, where we consider the number of POIs it took to cover the OHCAs, is shown in *Figure 8*.

Figure 9 gives the proportion of each POI that covered the OHCAs under assumed and actual coverage. It shows significant variation and differences between the two coverages. This could have cost-effectiveness implications.

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TABLE 24 Numbers of OHCAs covered by registered AEDs and if a new AED was placed in every POIs in the country

POI	Number	Number (%) of OHCAs covered			Number of POI that covered the OHCAs	
		By POI only (ignoring registered AEDs)	By POI if not covered by a registered AED	By a registered AED or a POI	By POI only (ignoring registered AEDs)	By POI if not covered by a registered AED
Registered AEDs	32,393	57,134 (38.8)				
Pubs	37,828	58,423 (39.6)	26,413 (29.3)	83,560 (56.7)	19,277	10,576
Post offices	8123	35,473 (24.0)	15,592 (17.3)	72,728 (49.4)	6542	4094
Places of worship	41,265	76,109 (51.6)	37,630 (41.7)	94,786 (64.3)	23,516	14,718
Chemists and pharmacies	11,541	49,535 (33.6)	20,407 (22.6)	77,549 (52.7)	9862	5937
Dental surgeries	8677	37,081 (25.2)	14,290 (15.9)	71,428 (48.5)	7297	4209
General practitioner surgeries	8621	38,112 (25.9)	14,491 (16.1)	71,629 (48.6)	7108	4152
Cash machines	38,890	81,312 (55.1)	41,461 (46.0)	98,635 (67.0)	24,532	15,190
Banks and building societies	8226	19,570 (12.6)	5784 (6.3)	62,923 (42.6)	4842	1995
Nursing and residential care homes	18,616	53,623 (36.4)	28,473 (31.7)	85,623 (58.1)	13,922	9834
Halls and community centres	17,604	49,534 (30.9)	23,598 (24.5)	80,741 (53.8)	11,898	7642
Gyms, sports halls and leisure centres	17,675	45,158 (30.7)	20,672 (22.9)	77,824 (52.8)	11,377	7326
Supermarket chains	6429	27,913 (18.9)	11,025 (12.2)	68,170 (46.3)	5399	3284
State first, primary and infants schools	16,653	52,165 (35.4)	27,025 (30.0)	84,164 (57.1)	12,399	8752
State secondary schools	3453	10,919 (7.4)	4984 (5.5)	62,119 (42.2)	2624	1791
All state schools	20,106	57,781 (39.2)	30,017 (20.4)	87,151 (59.2)		

TABLE 25 Assumed and actual coverage, coverage loss and efficiency if AEDs were to be deployed at various POIs

POI	POI number	By POI only (ignoring registered AEDs)				By POI if not covered by a registered AED				By a registered AED or POI			
		Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency
Pubs	37,828	58,423	31,892	45.4	84.3	26,426	14,578	44.8	38.5	83,560	45,235	45.9	119.6
Post offices	8123	35,473	12,292	65.3	151.3	15,594	5256	66.3	64.7	72,728	24,311	66.6	299.3
Places of worship	41,265	76,109	32,646	57.1	79.1	37,652	16,202	57.0	39.3	94,786	40,639	57.1	98.5
Chemists and pharmacies	11,541	49,535	18,373	62.9	159.2	20,415	7516	63.2	65.1	77,549	28,266	63.6	244.9
Dental surgeries	1721	4256	2336	45.1	135.7	3228	1768	45.2	102.7	4933	2682	45.6	155.8
General practitioner surgeries	8621	38,112	12,570	67.0	145.8	14,294	4761	66.7	55.2	71,629	23,502	67.2	272.6
Cash machines	38,890	81,312	81,312	0.0	32.3	41,501	41,501	0.0	106.7	98,635	98,635	0.0	253.6
Banks and building societies	8226	19,570	6459	67.0	78.5	5789	1893	67.3	23.0	62,923	18,939	69.9	230.2
Nursing and residential care homes	18,616	53,623	53,623	0.0	288.0	28,489	28,489	0.0	153.0	85,623	85,623	0.0	460.0
Halls and community centres	17,604	49,534	49,534	0.0	281.4	23,607	23,607	0.0	134.1	80,741	80,741	0.0	458.7
Gyms, sports halls and leisure centres	17,675	45,158	27,896	38.2	157.8	20,690	12,922	37.5	73.1	77,824	48,074	38.2	272.0
Supermarket chains	6429	27,913	17,591	37.0	273.6	11,036	6938	37.1	107.9	68,170	41,918	38.5	652.0
State first, primary and infants schools	16,653	52,165	11,486	78.0	69.0	27,030	5913	78.1	21.9	84,164	18,908	77.5	113.5
State secondary schools	3453	10,919	2379	78.2	68.9	4985	1076	78.4	31.2	62,119	14,071	77.3	407.5
All state schools	20,106	57,781	12,730	78.0	63.3	30,017	6573	78.1	190.4	87,151	19,568	77.5	566.7

Note
Assumed coverage means AED would be accessible 24/7; Actual coverage means AED was accessible only during operational times at POIs; Coverage loss equals assumed coverage minus actual coverage divided by assumed coverage; Coverage efficiency equals number of OHCAs covered divided by the number of POIs.

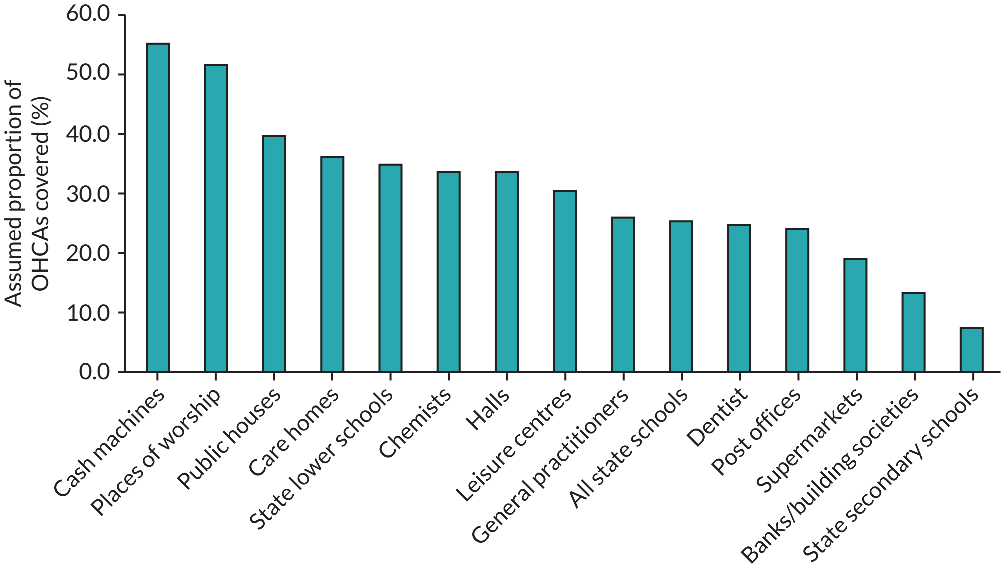

FIGURE 5 Assumed coverage of OHCAs of AEDs deployed at POIs.

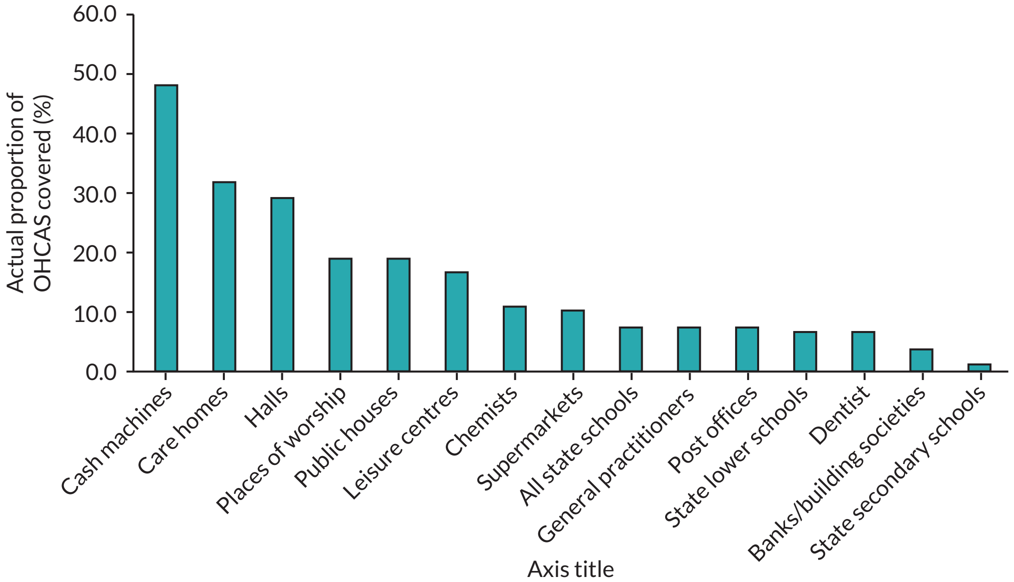

FIGURE 6 Actual coverage of OHCAs of AEDs deployed at POIs.

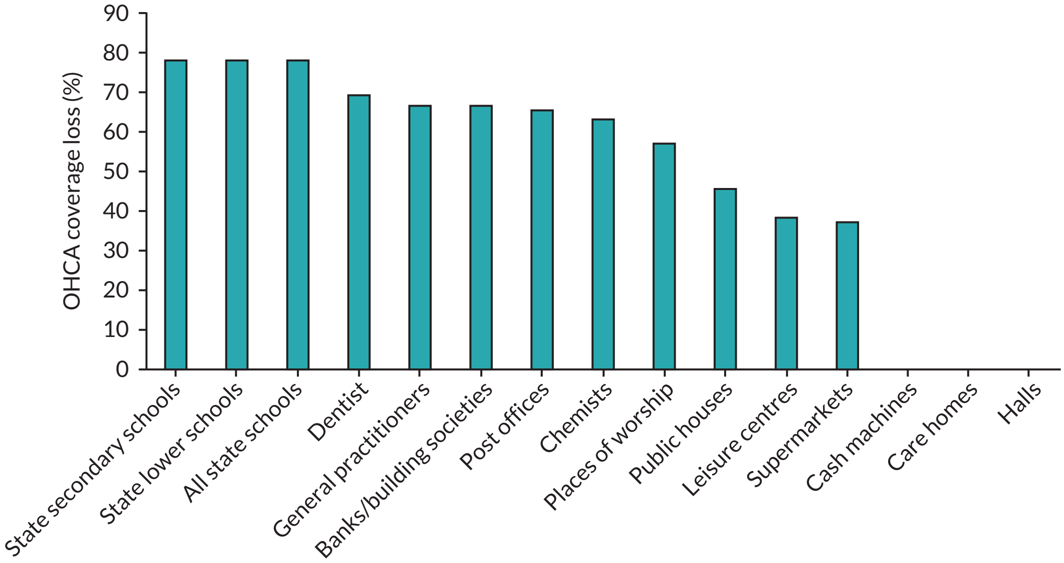

FIGURE 7 Coverage loss of OHCAs of AEDs deployed at POIs.

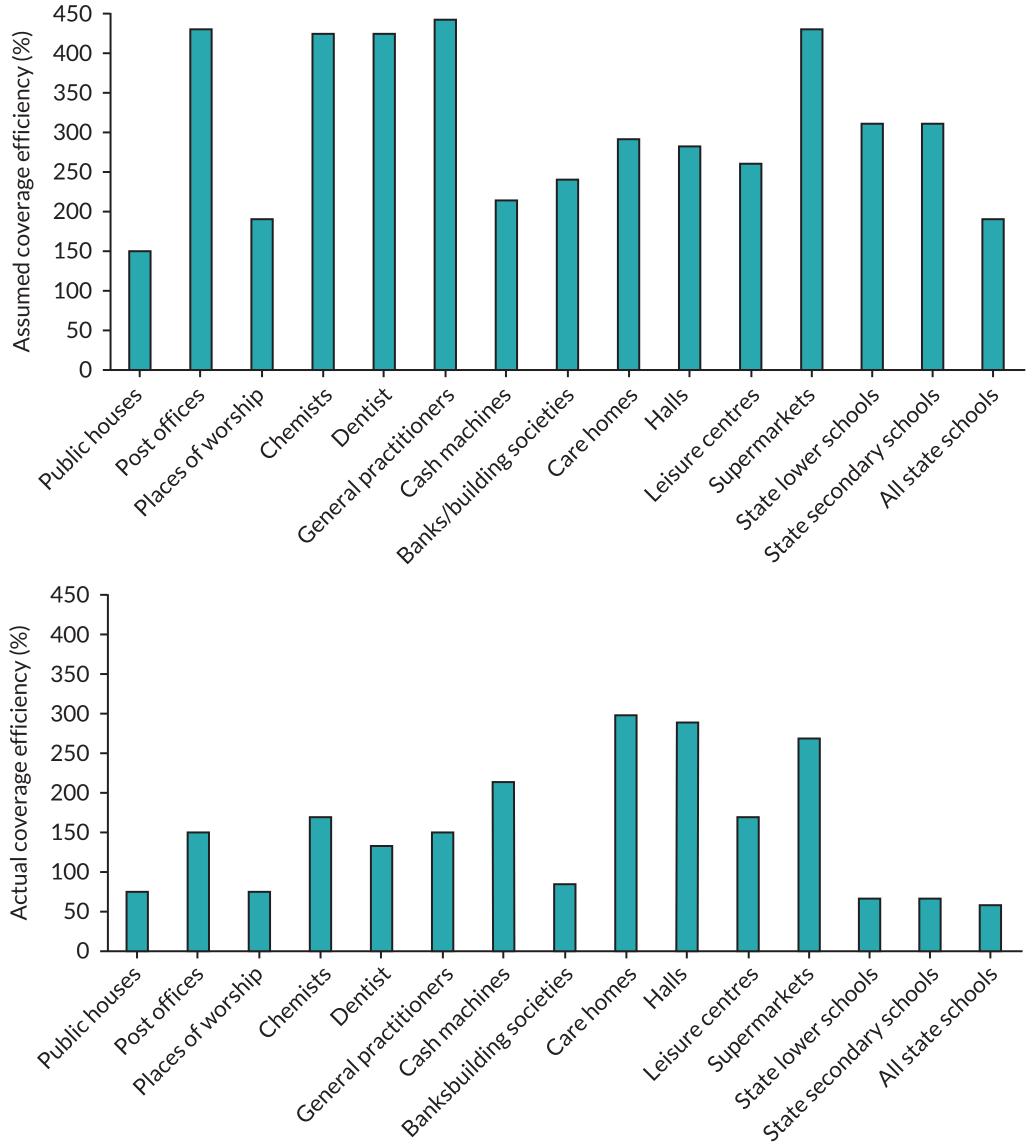

FIGURE 8 Coverage efficiency of OHCAs of AEDs deployed at POIs, assuming AEDs would be available 24/7 (upper panel) or actual coverage (lower panel) when AEDs would be available during opening time only.

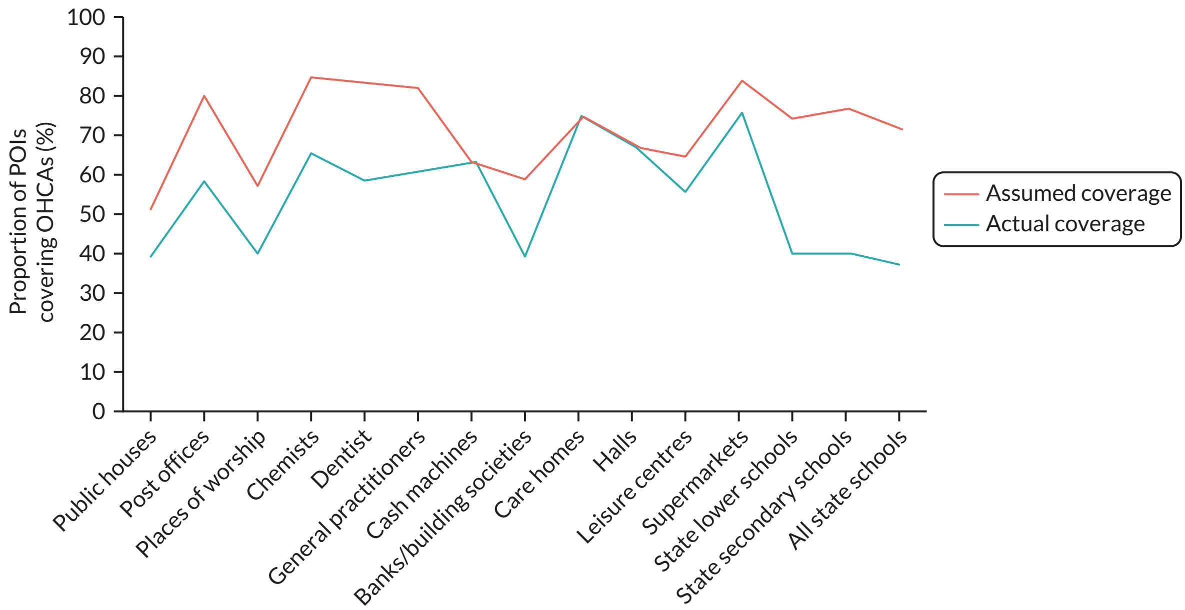

FIGURE 9 Proportion of POIs that cover OHCAs (500 m) under assumed and actual coverage.

There were 17,646 (12.0%) OHCAs that did not occur within 500 m of an existing AED or one of the POIs analysed above. When examining 100 m there were 107,357 (72.9%) OHCAs not covered, and 10,850 (7.4%) when looking at 1000 m.

Coverage in urban and rural areas

Table 26 gives the OHCA coverage loss and efficiency of POIs in urban and rural areas. Coverage loss is clearly similar in both areas, slightly less in rural areas. Efficiency is slightly greater in urban areas, mainly because more OHCAs occur in urban areas (see *Appendix 8*).

Characteristics of lower-level super output areas: covered versus uncovered

Table 27 shows the characteristics of OHCAs that were covered and not covered if an AED was located at one of the POIs. For all POIs the OHCAs not covered were in areas with a significantly lower residential and workday population density. The proportion of the population indicating they were from white ethnic background was significantly higher in uncovered OHCAs, whereas the proportion indicating they were from non-white ethnic background was lower. Areas where OHCAs were not covered also contained a greater proportion of the population who were aged 65 years and over. OHCAs not covered were also in more affluent areas, that is, IMD was higher. What this shows is that to some extent deploying AEDs at any of the POIs would reduce some of the health inequalities currently seen in relation to ethnicity and IMD highlighted in *Automated external defibrillators*.

One-square-kilometre grids

As would be expected, considering the number of 1 km^2 grids in England, OHCA coverage was significantly high irrespective of what distance we looked at (*Table 28*). Approximately 80% of all OHCAs occurred within 500 m of a 1 km^2 grid centroid, with an ambulance service range of 78% in SCAS to 84.1% in IOWAS. When looking at AEDs within 300 and 100 m the OHCA coverage was 28.5% and 3.1%, respectively.

Census output areas

Coverage by COA centroids was significantly lower than that of 1 km^2 grid centroids by more than 50% at 500 m and 1.0% at 100 m (*Table 29*). At 500 m, coverage was 23.4% (range 16.8% in LAS to 5.05% in IOWAS), and at 100 m was 2.1% (range 2.1% in LAS to 7.1% in IOWAS). Comparison of the cumulative coverage shows that at about 700 m it would be 100% if an AED was placed in the centre of every 1 km^2 grid, whereas for COA centroids 100% coverage is not reached until we extend the radius of operation to over 3000 m (*Figure 10*).

Optimisation method

We ran the optimisation model on an ambulance service regional basis. However, it could be applied on any geographic scale, for example city or country, depending on the availability (and accuracy) of information and computer processing power. *Figures 11–13* show the increase in OHCA coverage within the West Midlands, Isle of Wight and NWAS regions, if an AED were placed in every location of the following POIs: pubs, places of worship, primary schools, secondary schools, community halls and care homes, compared to OHCA coverage levels if AED locations were chosen from evenly spaced points 1 km apart throughout the ambulance service's region, up to a maximum of 1500 locations. Similar graphs for all ambulance service regions can be found in *Appendix 10*.

These results show that even if AEDs were blanketly placed in each location of a POI, 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 OHCA coverage of 17.8% above that provided by existing registered AEDs (see *Figure 11*). However, the same amount of added OHCA coverage could be achieved with only 250 optimised grid points spaced 1 km apart. In fact, the efficiency of coverage provided by the optimised grid points was unmatched by any type of POI. Automated external defibrillator placement in state secondary schools provided the lowest coverage gains for all regions, although the number of AEDs placed was also the least, while AED placement in places of worship led to the greatest gains in coverage albeit at the cost of having to place thousands of AEDs. On the Isle of Wight coverage is already high, but with an additional 30–40 AEDs optimally placed it could potentially approach 100% (see *Figure 12*). In the North-West there is a different picture in that to reach about 90% coverage over 2000 AEDs would be required (see *Figure 13*).

TABLE 26 Out-of-hospital cardiac arrest coverage loss and efficiency if AEDs were deployed at various POIs: a comparison of urban and rural locations

	Number of POIs		Coverage loss (%)		Coverage efficiency (%)	
	Urban	Rural	Urban	Rural	Urban	Rural
Pubs	27,829	9999	45.7	43.2	99.9	40.9
Post offices	4920	3203	65.3	65.6	214.0	55.0
Places of worship	24,175	17,090	57.3	55.9	118.2	23.8
Chemist	10,300	1241	63.0	61.4	165.8	104.1
Dentist	7724	953	69.2	67.2	138.6	78.2
General practitioner	6927	1694	67.2	65.6	164.5	69.5
Automatic teller machine	34,727	4163	0.0	0.0	218.0	134.5
Banks	7608	618	67.0	66.5	161.1	137.9
Care homes	14,995	3621	0.0	0.0	325.9	131.4
Community hall	10,628	6976	0.0	0.0	408.8	87.3
Leisure centre	14,181	3494	38.5	34.4	184.1	51.0
Supermarket	5431	998	37.2	34.7	293.8	163.7
State primary schools	11,831	4822	78.0	77.8	87.6	23.4
State secondary schools	2955	498	78.3	76.4	75.8	27.9
All state schools	14,786	5320	78.0	77.6	77.8	23.0

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TABLE 27 Neighbourhood characteristics (mean, SD) of LSOAs where OHCAs occurred that would be covered or not if an AED was placed in the selected POI

	Covered						Not covered					
	Population density (km²)		Proportion of population (%)				Population density (km²)		Proportion of population (%)			
POI	Residential	Workday	Indicating white	Indicating non-white	Aged 65 years and over	IMD decile	Residential	Workday	Indicating white	Indicating non-white	Aged 65 years and over	IMD decile
Public houses	58.2 (52.3)	71.4 (113.2)	81.7 (21.5)	15.9 (20.2)	15.9 (7.6)	4.6 (2.7)	36.9 (32.9)	30.4 (27.8)	86.5 (19.6)	11.6 (18.5)	17.8 (7.3)	5.2 (2.9)
Post offices	55.8 (50.4)	70.4 (117.5)	81.6 (22.8)	16.1 (21.6)	16.3 (7.6)	4.4 (2.7)	42.0 (39.8)	39.2 (56.9)	85.6 (19.6)	12.4 (18.4)	17.3 (7.4)	5.2 (2.9)
Place of worship	57.6 (50.0)	64.3 (97.1)	80.2 (23.3)	17.3 (22.0)	15.8 (7.4)	4.4 (2.7)	32.3 (28.6)	27.8 (40.0)	89.3 (15.6)	9.0 (14.7)	18.4 (7.3)	5.6 (2.9)
Chemists	65.4 (52.2)	79.6 (117.0)	77.1 (24.3)	20.1 (23.1)	15.0 (7.3)	4.2 (2.7)	35.2 (33.1)	30.0 (34.9)	88.4 (17.1)	9.8 (15.9)	18.1 (7.3)	5.4 (2.8)
Dentists	68.5 (53.8)	87.9 (130.4)	76.7 (24.0)	20.5 (22.8)	15.1 (7.5)	4.5 (2.7)	37.6 (35.4)	32.8 (38.5)	87.3 (18.4)	10.8 (17.2)	17.7 (7.3)	5.2 (2.9)
General practitioners	67.6 (55.1)	73.6 (94.5)	76.1 (25.1)	21.0 (23.9)	15.0 (7.3)	4.2 (2.6)	37.6 (34.6)	37.3 (67.7)	87.6 (17.7)	10.6 (16.5)	17.8 (7.4)	5.3 (2.9)
Automatic teller machines	59.4 (48.0)	65.8 (97.5)	79.9 (22.8)	17.5 (21.6)	15.3 (7.1)	4.2 (2.7)	28.1 (27.3)	23.1 (23.9)	90.4 (15.3)	8.1 (14.5)	19.2 (7.3)	6.0 (2.7)
Banks	67.5 (54.2)	118.6 (173.4)	76.2 (24.0)	21.1 (22.9)	15.0 (8.0)	4.3 (2.6)	42.0 (39.9)	35.6 (36.8)	85.9 (19.6)	12.1 (18.4)	17.3 (7.3)	5.1 (2.9)
Care homes	55.1 (45.6)	54.9 (70.9)	81.7 (22.6)	15.9 (21.4)	17.1 (7.7)	4.5 (2.7)	39.8 (40.3)	42.0 (80.2)	86.3 (19.0)	11.7 (17.7)	17.0 (7.3)	5.2 (2.9)
Community halls	60.1 (53.0)	63.8 (89.3)	79.7 (23.8)	17.8 (22.5)	15.4 (7.3)	4.1 (2.7)	37.9 (34.5)	38.0 (68.6)	87.1 (18.1)	11.0 (17.0)	17.9 (7.4)	5.4 (2.8)
Leisure centres	65.4 (54.1)	81.4 (123.8)	77.2 (23.4)	19.8 (22.1)	14.2 (6.9)	4.1 (2.6)	36.5 (33.4)	31.3 (32.4)	87.9 (18.1)	10.4 (17.1)	18.3 (7.3)	5.4 (2.8)
Supermarkets	59.5 (50.2)	75.8 (112.3)	81.9 (20.6)	15.6 (19.2)	15.8 (7.5)	4.4 (2.7)	42.1 (40.4)	39.9 (64.5)	85.2 (20.4)	12.8 (19.3)	17.3 (7.4)	5.1 (2.9)
State primary schools	60.7 (52.1)	59.6 (79.0)	79.9 (23.5)	17.5 (22.2)	15.3 (6.8)	4.3 (2.8)	36.9 (34.2)	39.6 (75.3)	87.2 (18.1)	11.0 (17.0)	18.0 (7.6)	5.4 (2.8)
State secondary schools	68.3 (57.8)	70.1 (79.5)	75.1 (25.3)	22.0 (24.1)	14.9 (7.1)	4.4 (2.6)	43.5 (41.0)	44.8 (76.7)	85.4 (19.9)	12.6 (18.7)	17.2 (7.5)	5.0 (2.9)

TABLE 28 Number (%) of OHCAs covered if an AED was located at the centre of every 1 km^2 grid square

Service	OHCA total	OHCAs within 500 m of a registered AED	OHCAs within specified distance of 1 km^2 grid centroid			OHCAs within 500 m of a registered AED or 1 km^2 grid centroid
			500 m	300 m	100 m	
EEAS	5202	1140 (21.9)	4139 (79.6)	1465 (28.2)	176 (3.4)	4546 (87.4)
EMAS	11,665	5534 (47.4)	9148 (78.4)	3208 (27.5)	348 (3.0)	10,897 (93.4)
IOWAS	182	114 (62.6)	153 (84.1)	59 (32.4)	8 (4.4)	174 (95.6)
LAS	26,236	16,737 (63.8)	20,743 (79.1)	7873 (30.0)	758 (2.9)	25,536 (97.3)
NEAS	11,330	1705 (15.0)	8975 (79.2)	3248 (28.7)	368 (3.2)	9526 (84.1)
NWAS	21,987	6854 (31.2)	17,200 (78.2)	6132 (27.9)	684 (3.1)	19,388 (88.2)
SCAS	7886	2744 (34.8)	6155 (78.0)	2249 (28.5)	258 (3.3)	7087 (89.9)
SECAmb	13,270	5573 (42.0)	10,513 (79.2)	3705 (27.9)	417 (3.1)	12,261 (92.4)
SWAST	17,537	4982 (28.4)	13,931 (79.4)	5090 (29.0)	532 (3.0)	15,554 (88.7)
WMAS	22,444	9969 (44.4)	17,583 (78.3)	6314 (28.1)	663 (3.0)	20,838 (92.8)
YAS	9539	1782 (18.7)	7476 (78.4)	2677 (28.1)	294 (3.1)	8094 (84.9)
Total	147,278	57,134 (38.8)	116,016 (78.8)	42,020 (28.5)	4506 (3.1)	133,901 (90.9)

TABLE 29 Number (%) of OHCAs covered if an AED was located at the centre of every COA

Service	Total	OHCAs within 500 m of a registered AED	OHCAs within 500 m of COA centroid	OHCAs within 500 m of a registered AED or centroid	OHCAs within 300 m of COA centroid
EEAS	5202	1140 (21.9)	1427 (27.4)	2778 (53.4)	743 (14.3)
EMAS	11,665	5534 (47.4)	3283 (28.1)	9071 (77.8)	1688 (14.5)
IOWAS	182	114 (62.6)	92 (50.5)	154 (84.6)	64 (35.2)
LAS	26,236	16,737 (63.8)	4410 (16.8)	22,996 (87.7)	1940 (7.4)
NEAS	11,330	1705 (15.0)	2944 (26.0)	4796 (42.3)	1474 (13.0)
NWAS	21,987	6854 (31.2)	4666 (21.2)	12,548 (57.1)	2190 (10.0)
SCAS	7886	2744 (34.8)	1987 (25.2)	5128 (65.0)	995 (12.6)
SECAmb	13,270	5573 (42.0)	3836 (28.9)	9522 (71.8)	1981 (14.9)
SWAST	17,537	4982 (28.4)	4676 (26.7)	9961 (56.8)	2478 (14.1)
WMAS	22,444	9969 (44.4)	4944 (22.0)	16,447 (73.3)	2459 (11.0)
YAS	9539	1782 (18.7)	2289 (24.0)	4317 (45.3)	1167 (12.2)
Total	147,278	57,134 (38.8)	34,554 (23.4)	97,718 (66.3)	17,179 (11.7)

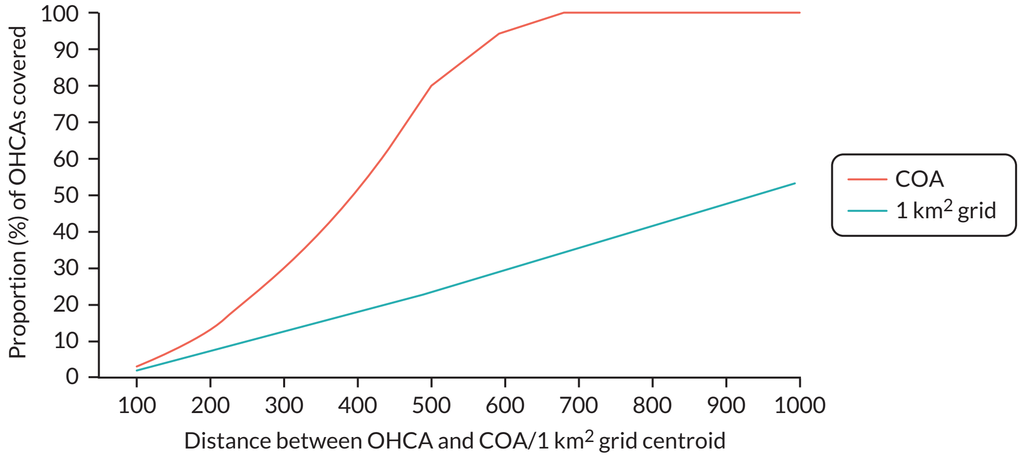
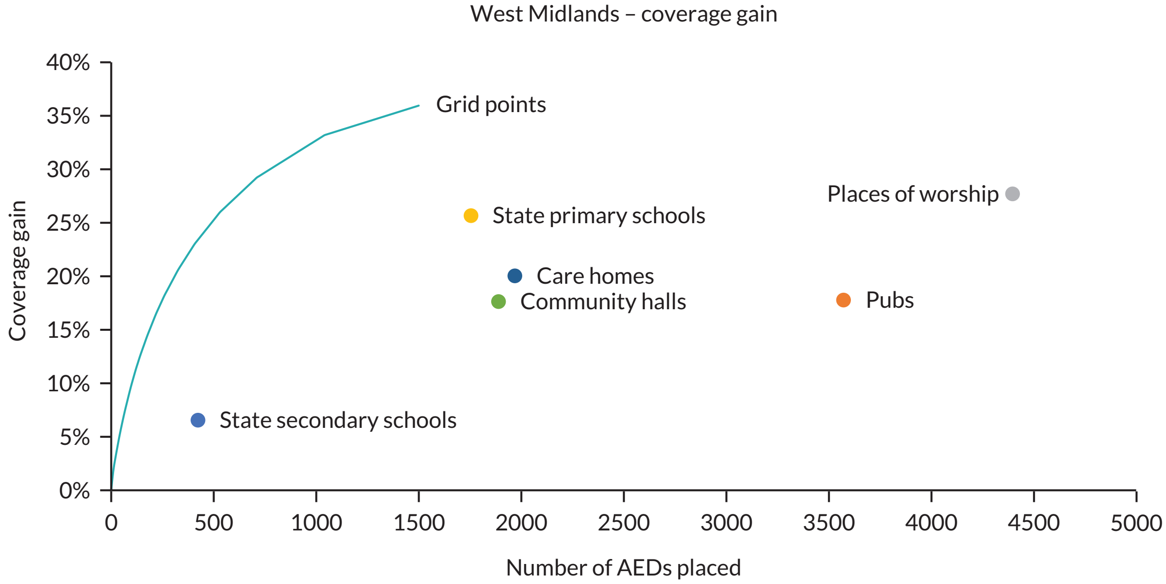


FIGURE 10 Out-of-hospital cardiac arrest coverage with increasing OHCA–AED distance.



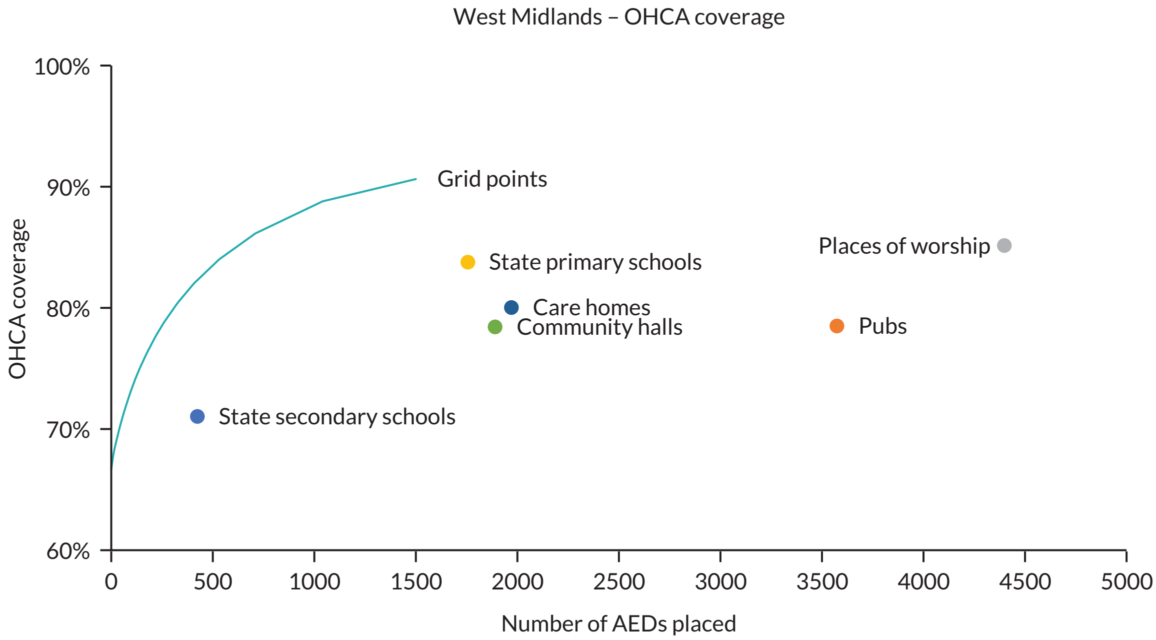


FIGURE 11 Comparison of OHCA coverage gains and coverage levels using optimisation and POI approaches in the region served by WMAS.

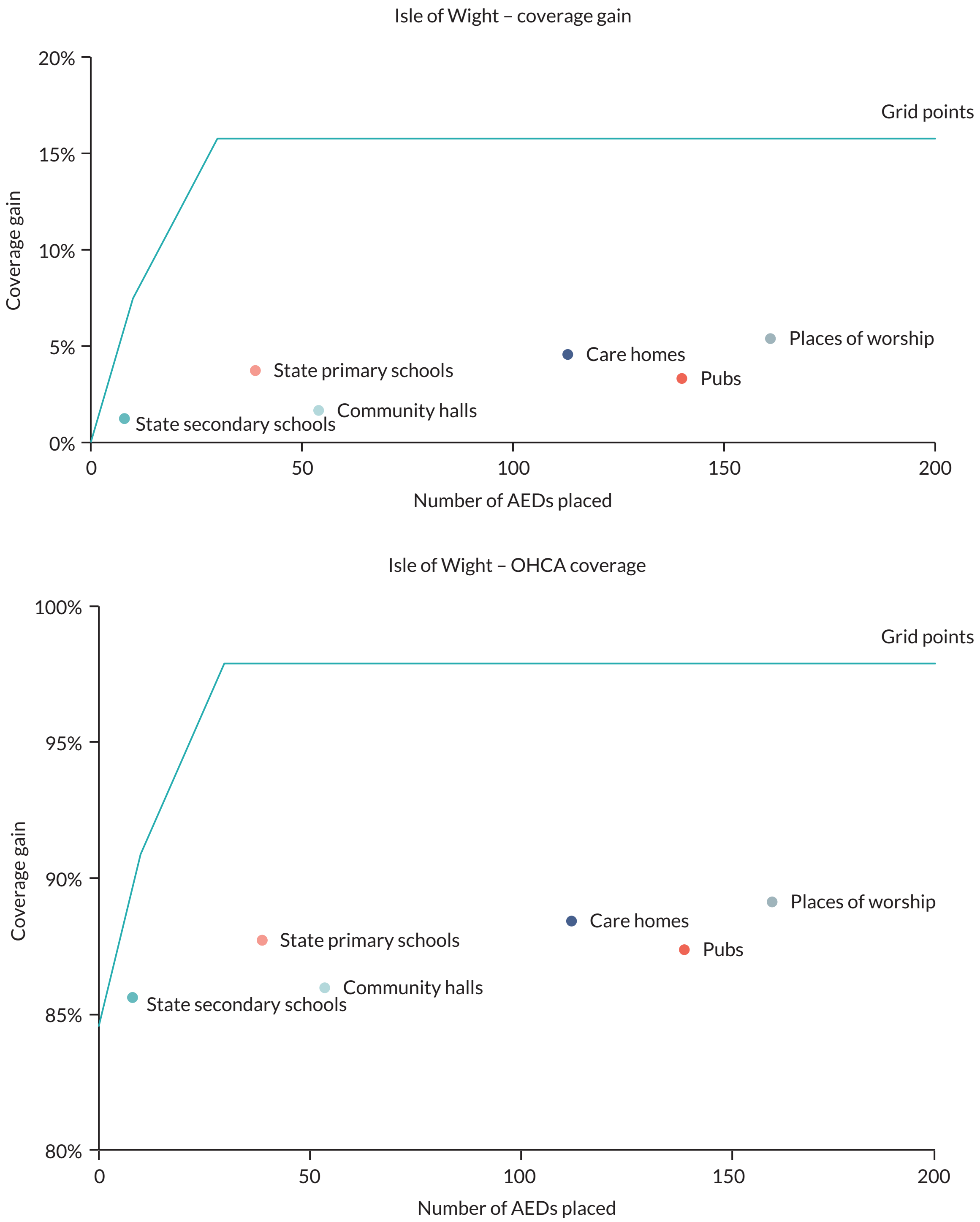


FIGURE 12 Comparison of OHCA coverage gains and coverage levels using optimisation and POI approaches in region served by IOWAS.

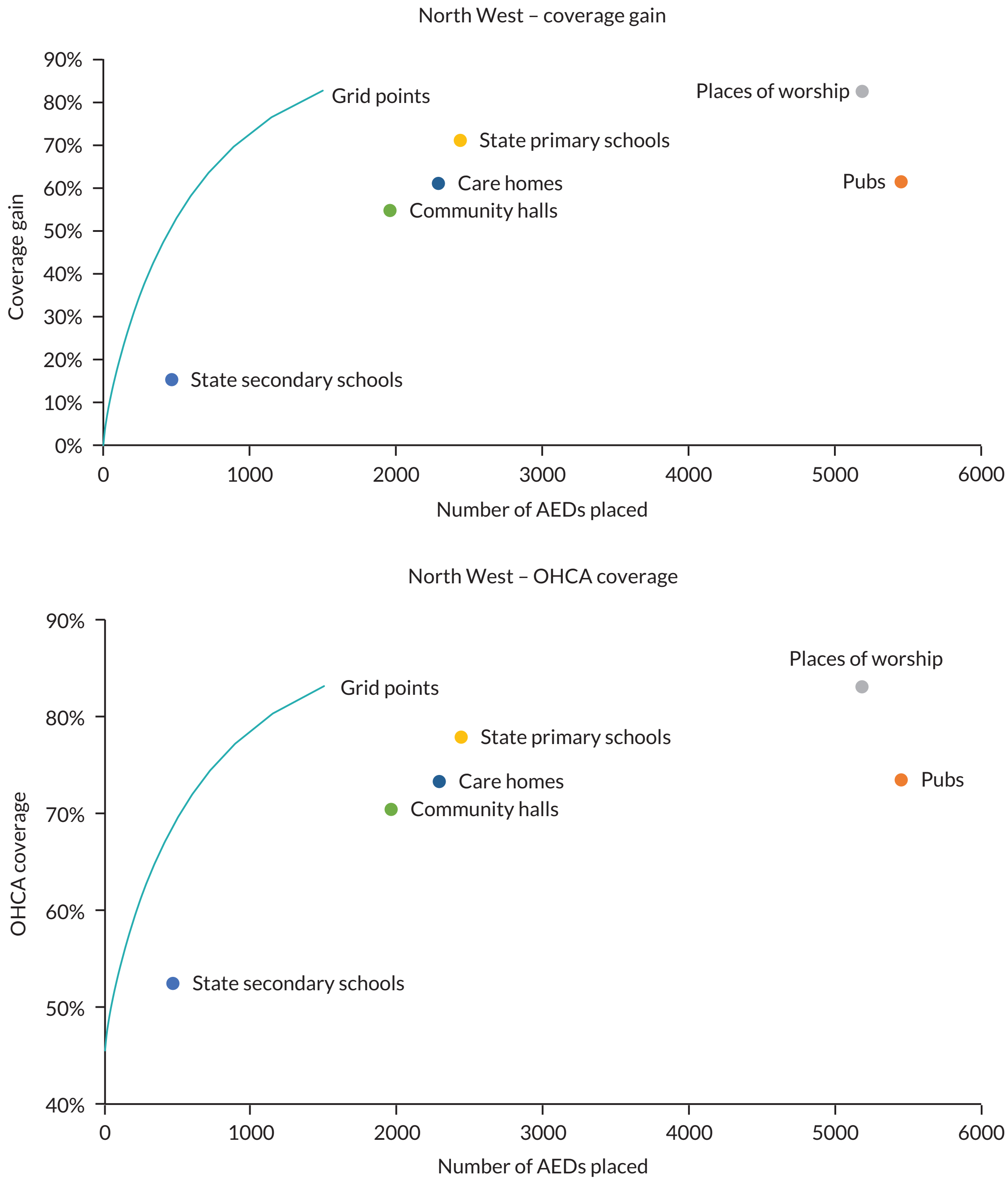


FIGURE 13 Comparison of OHCA coverage gains and coverage levels using optimisation and POI approaches in the region served by NWAS.

Analysis of information from each ambulance service region shows that using mathematical optimisation to select POIs for new AEDs, accounting for locations of historical OHCAs and existing registered AEDs, could provide substantially higher improvements in OHCA coverage compared to POI-based approaches given a fixed number of AED locations. Also, historical OHCA locations could be covered using fewer new AED locations compared to the POI-based approach. These findings suggest that an optimisation-based approach could provide higher coverage of OHCA locations while reducing the number (and therefore cost) of placing new AEDs. Another advantage of the method is that it identifies the 1 km^2 grids that would improve the coverage.

Work package 3: cost-effectiveness analysis

The aim of this WP was to determine the costs and benefits associated with public automated defibrillator placement strategies in each of a series of POIs and compare these against current AED placement.

Base-case analysis

The results of the base-case analysis assume actual coverage, that is, normal working hours. Differences in costs and outcomes (QALYs and LYG) were calculated directly from the model and were converted into ICERs for QALYs and LYG (*Table 30*). As the comparison involved more than two mutually exclusive treatments, ICERs were calculated by sorting the treatments in order of increasing cost, eliminating dominated treatments and comparing the remaining options.[122,135]

Unsurprisingly, results showed that all placement scenarios were associated with a greater expected total cost compared to current AED placement. This ranged from an additional £8 (state secondary schools) to £386 (cash machines). In relation to outcomes, all placement scenarios showed an increase in QALYs and LYGs. In most cases, this was small, ranging from a marginal 0.0002 QALYs (0.0003 LYGs) for state secondary schools to 0.011 QALYs (0.02 LYGs) for cash machines.

When comparing alternative deployments, different options were either extendedly dominated (i.e. the ICER for a placement was higher than that of the next more effective placement) or simply dominated (i.e. a placement was both more costly and less effective than an alternative placement). After removing dominated options, the most cost-effective option was halls and community centres. Compared to CP, this deployment option resulted in higher costs (£223; 95% CI generated from 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 ICER of £32,418 per QALY (£18,893 per LYG). This value is above the

TABLE 30 Base-case results

	Total expected cost (£)	Total expected QALYs	Total expected LYG	Difference in costs (POI vs. current) (£)	Difference in QALYs (POI vs. current)	Difference in LYG (POI vs. current)	ICER (£ per additional QALY) (£)	ICER (£ per additional LYG) (£)
Current	8762	0.233	0.402	–	–	–	–	–
Alternative placements								
Public houses, bars and inns	8917	0.238	0.409	155	0.004	0.007	38,034	22,166
Post office	8801	0.234	0.404	39	0.001	0.002	37,683	21,962
Place of worship	8905	0.237	0.409	143	0.004	0.006	39,453	22,993
Chemists and pharmacies	8818	0.235	0.405	56	0.001	0.003	38,183	22,253
Dental surgeries	8791	0.234	0.404	29	0.001	0.001	38,629	22,513
Doctors' surgeries	8793	0.234	0.404	31	0.001	0.001	38,103	22,206
Cash machines	9148	0.245	0.422	386	0.011	0.020	33,779	19,687
Banks and building societies	8775	0.234	0.403	13	0.000	0.001	39,279	22,892
Nursing and residential care homes	9013	0.241	0.415	251	0.008	0.013	32,870	19,157
Halls and community centres	8985	0.240	0.414	223	0.007	0.012	32,418	18,893
Gyms, sports halls and leisure centres	8878	0.237	0.408	116	0.003	0.006	35,908	20,927
Supermarket chains	8828	0.235	0.406	66	0.002	0.003	34,671	20,206
State first, primary and infant schools	8804	0.234	0.404	42	0.001	0.002	41,339	24,092
State secondary schools	8770	0.234	0.403	8	0.000	0.000	42,315	24,661

upper bound of the £20,000–30,000 per QALY range that is often seen as threshold considered for decision-making in health care.[120,123,146,147] A cost-effectiveness plane showing the results of the (deterministic) base-case analysis can be found in *Figure 14*. Cost-effectiveness results obtained from the model when this was run probabilistically were plotted in cost-effectiveness planes (CE planes) and CEACs (*Figures 15* and *16*). Cost-effectiveness planes depict the simulated additional cost/outcomes pairs in a four-quadrant plane demarcated by an additional cost axis (*y*-axis) and an additional outcome axis (*y*-axis). All the 5000 simulated cost and QALY pairs were located in the top right (North-East) quadrant, indicating that, compared to CP, additional deployment of AEDs in halls and community centres would result in higher costs and a greater number of QALYs (see *Figure 15*) or LYGs (see *Figure 16*).

Cost-effectiveness acceptability curves representing the probability of additional hall and community centre deployment being cost-effective for ceiling ratio values ranging from £0 to £80,000 are given in *Figure 17*. If a decision-maker is not willing to pay any additional amount for extra health benefits (i.e. the ceiling ratio is zero), there is a zero probability that alternative placement in halls and community centres (or any alternative placements) can be perceived as cost-effective. At ceiling ratios between £20,000 and £30,000 per QALY, the probability of alternative placement in halls and community centres rises from 0.2% to 30% and exceeds 50% at ceiling ratios higher than the ICER. At a high ceiling ratio value of £80,000 per QALY, there is almost certainty that alternative placement can be perceived as cost-effective compared to CP, showing a probability of over 99%.

Findings were also cross-examined by looking at the relative efficiency (in terms of improvement in the probability that an OHCA case would be within 500 m of an AED) of an additional AED installed at each assessed landmark. *Table 31* shows the number of additional AEDs required for each landmark deployment strategy, the probability that an AED would be available within 500 m given the deployment of additional landmarks, and a calculated ratio of the improvement in the probability of AED availability (compared to CP) divided by the number of additional AEDs required (scaled up to 1000 AEDs to help with interpretability). This ratio ranged from a modest increase of 0.95% in the AED availability per 1000 AEDs for secondary schools to 2.27% for nursing and residential care homes and 2.43% for halls and community centres.

Sensitivity analyses

Findings of deterministic sensitivity analyses, carried out to examine the sensitivity of the results to different values of key model parameters, are given in *Appendix 2*, *Table 40*.

Alternative values for probability parameters had a small effect on the ICER. An exception to this was an analysis in which the probability that a patient was discharged from hospital alive, given that an AED was used, was set to be the same as the probability that a patient was discharged from hospital alive where an AED was not used. In this case, the ICER increased to nearly £45,000 per QALY, an increase by approximately 39%. Similarly, most alternative values for key cost parameters led to changes in the ICER, the most sizeable of which was when 25% was added (subtracted) from cost of post-discharge care during the first year for patients with CPC 3 or 4 functional status. In this case, the ICER rose (decreased) by approximately 11% compared to the base-case ICER. Alternative values of the proportion of patients classified in each CPC category (1–4) at discharge led to a moderate decrease in the base-case ICER. Most notably, using values employed in a recent economic evaluation by Andersen *et al.*[126] led to a decrease in the ICER by just over 16%, resulting in a more appealing ICER of £27,100 per additional QALY. Last, reducing and extending the time horizon (5 and 20 years) resulted in changes in the ICER: the shorter time horizon increased the ICER for additional AED deployment in halls and community centres (£40,900 per QALY, 26% increase compared to base-case ICER), while the 20-year time horizon led to a nearly 20% reduction in the ICER, to £26,000 per QALY. Notwithstanding these changes, ICER values were relatively insensitive to changes in single parameters (or sets of linked parameters).

Results of scenario analyses can be found in *Appendix 11*, *Tables 85–87*. For scenario 1, assuming that AEDs are available on a 24/7 basis implies greater availability in covering OHCAs, which shifts ICERs to more favourable values. Under this scenario, the most cost-effective deployment would be in pubs, bars and inns, with an ICER of £32,093 per additional QALY. Changing the reference distance for estimating coverage from 500 to 100 m or 1000 m changes the probability of coverage and the number of AEDs required, with the latter depending on existing AEDs and location of landmarks where an AED is not currently installed. The resulting ICERs depend on the balance between increased coverage for OHCAs and number of landmark locations where an AED is not already available. Assuming a distance of

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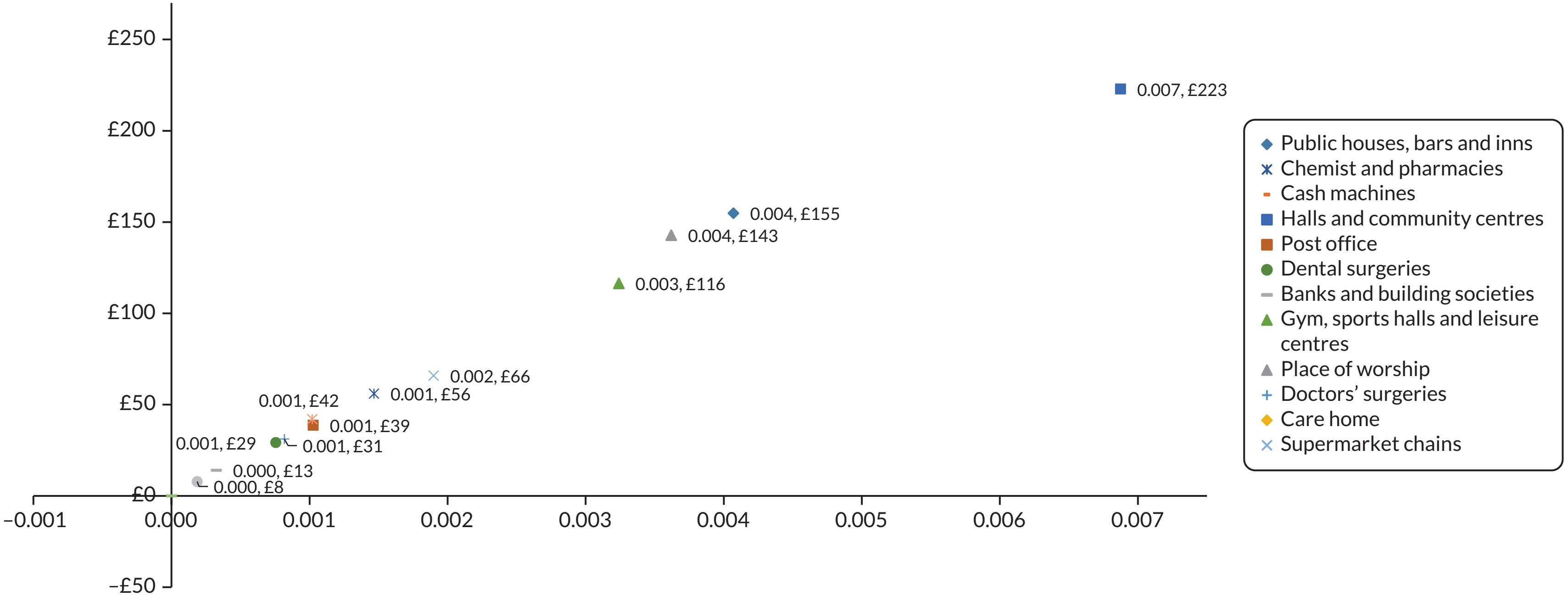

FIGURE 14 Cost-effectiveness plane showing deterministic (point estimate) results of base-case analysis (current placement vs. alternative placements).

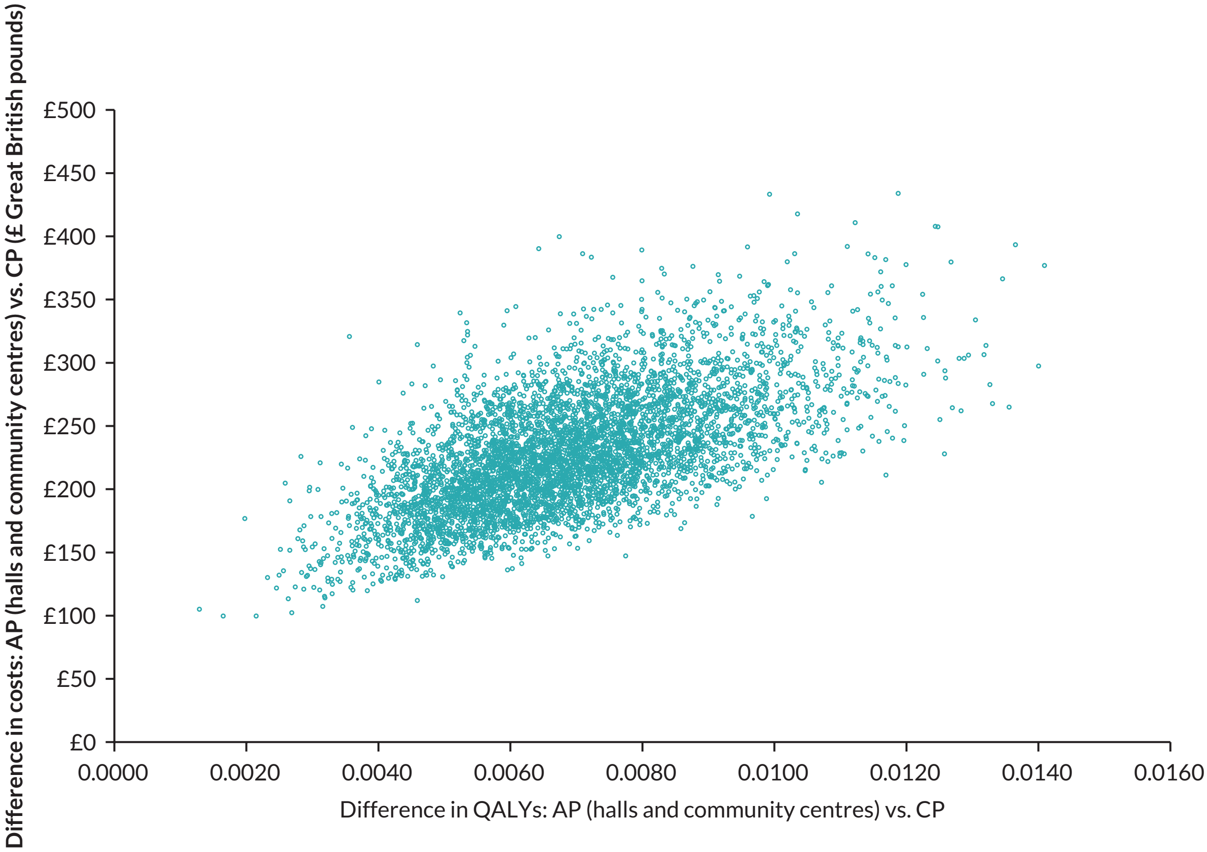

FIGURE 15 Cost-effectiveness plane depicting 5000 pairs of incremental costs and QALYs (halls and community centres vs. current placement) resulting from probabilistic analysis.

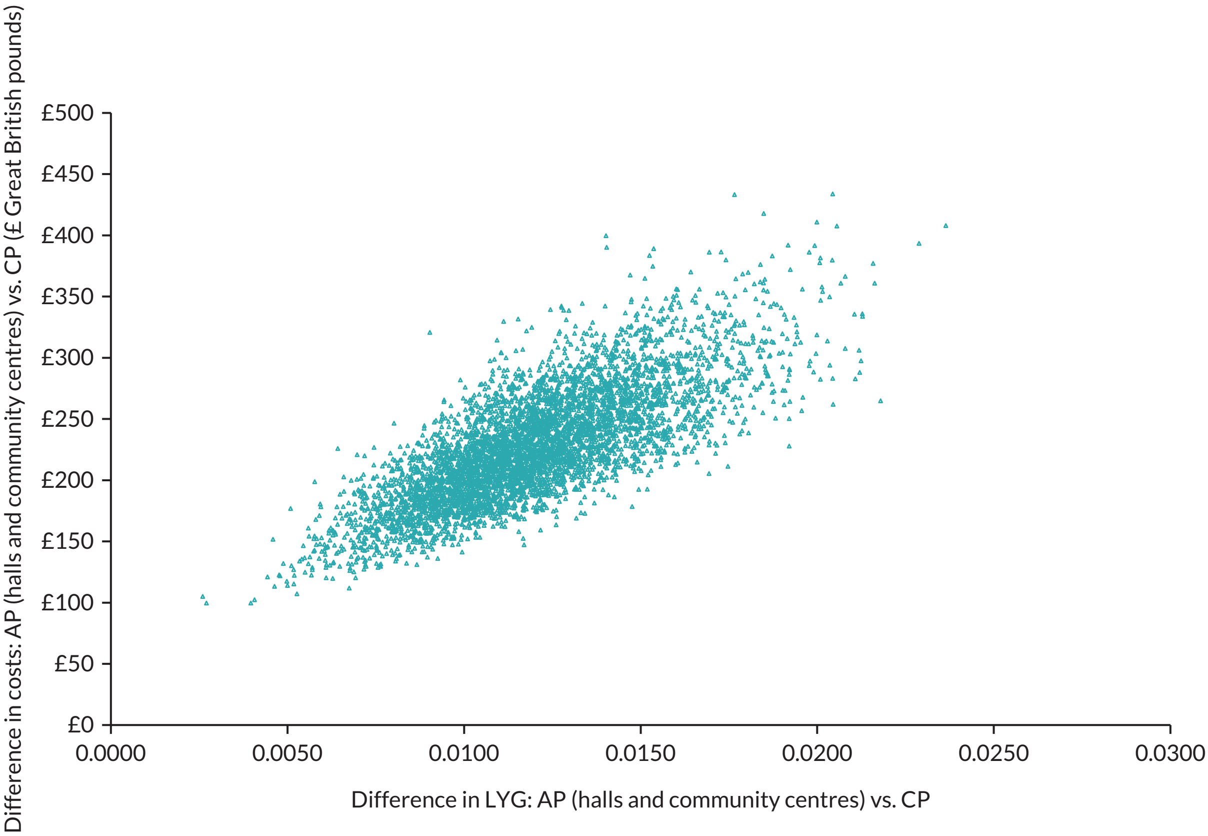

FIGURE 16 Cost-effectiveness plane depicting 5000 pairs of incremental costs and LYG (halls and community centres vs. current placement).

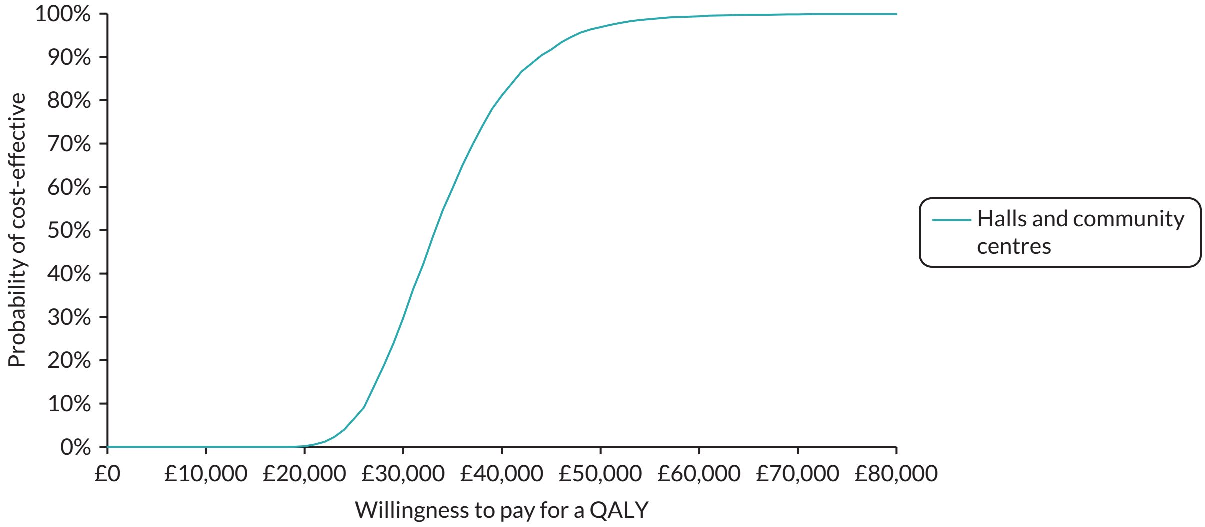

FIGURE 17 Cost-effectiveness acceptability curve depicting the probability of halls and community centres being cost-effective at different values of willingness to pay (vs. current placement, derived from probabilistic analysis on the basis of cost per additional QALY).

TABLE 31 Efficiency of additional AEDs installed

	Probability of AED being available within 500 m	Additional AEDs needed to achieve this probability	Increase in probability of AED being available compared to CP (per 1000 AEDs) (%)
CP	0.142	–	–
Public houses, bars and inns	0.303	12,468	1.29
Post office	0.182	3052	1.33
Place of worship	0.285	12,407	1.15
Chemists and pharmacies	0.200	4548	1.28
Dental surgeries	0.171	2431	1.23
Doctors' surgeries	0.174	2518	1.28
Cash machines	0.594	22,584	2.00
Banks and building societies	0.154	1099	1.17
Nursing and residential care homes	0.443	13,286	2.27
Halls and community centres	0.413	11,174	2.43
Gyms, sports halls and leisure centres	0.270	8161	1.57
Supermarket chains	0.217	4182	1.80
State first, primary and infant schools	0.182	3983	1.01
State secondary schools	0.149	774	0.95

100 m shifted the ICERs to over £40,000 per QALY, whereas setting the distance to 1000 m gave comparable ICERs to the base-case analysis.

Value-of-information analysis

The EVPI for the decision problem was carried out to establish whether conducting further research to confirm the results of the comparison between alternative placement (in this case, halls and community centres) and CP would be potentially worthwhile. Individual (per-patient) and population EVPI results are given in *Appendix 11* (see *Table 89* and *Figures 34* and *35*). For commonly referenced values of the willingness to pay (£20,000–30,000), there is little uncertainty that the ICER for halls and community centres does not fall within the above range. Consequently, the expected opportunity loss is small, and the maximum value of conducting further research on the basis of an individual patient is small (£8). However, when the individual patient EVPI is scaled up to the current and projected population that the analysis applies to, the population EVPI at £30,000 per QALY is sizeable, reaching £1.32M and indicating that further research to reduce uncertainty around the comparison would be potentially (although not necessarily) worthwhile, if it cost up to this value.

Work package 4: stakeholder meeting

At the stakeholder meeting several issues were raised and discussed, some related to the topic of this project, while others were outside the project's scope.

Automated external defibrillator deployment issues

There was consensus among the attendees that the current distribution of publicly accessible AEDs was suboptimal. How this could be solved was debated and all agreed that a strategic approach should be taken. AED accessibility was said to be a crucial factor, and that they, where possible, should be moved to the outside of buildings that would make them accessible 24/7 (42% of participants). For existing AEDs, attendees said that serious consideration should be given to optimising their accessibility and making them clearly visible to the public. It was also stressed that companies that purchased AEDs for their premises had a corporate responsibility to make them accessible to the local community and the general public in times of need.

What was the best method to determine where to deploy new AEDs was discussed, and 27% of participants suggested the POI approach was preferable. They stated that common locations, for example, old phone boxes, village halls and post offices should be considered so people would get to expect them there. It was also suggested that prominent boxes could possibly be located at busy road junctions. However, everyone agreed that it was key to make the local population aware of the locations. In relation to this, it was said that local planning authorities reviewing applications to build new premises, for example sports centres, car parks, shopping complex and motorway services, should put conditions on approvals that an AED is also deployed. This includes new housing estates, where every house should have a sticker indicating the location of the nearest AED.

It was agreed by 58% of participants that optimisation was the way forward. However, there was no general agreement about the optimal OHCA–AED distance that should be considered, although 60% said 200 m would be best. It was agreed that any guidance produced should vary between urban and rural areas, because even though there are similarities there are also some exceptional circumstances.

Any newly purchased AEDs should be deployed to improve inequalities in their provision, with serious consideration given to the local neighbourhood characteristics. Areas should be prioritised based on existing evidence; that is, those that lack a currently registered AED, have a high OHCA incidence, have a high population density, a greater proportion of minority ethnic groups and where the level of deprivation is high. It was agreed that this study would go a long way to assist people purchasing AEDs in deciding where to place them. Deprived areas should be given additional assistance in purchasing AEDs, because they also find it difficult to raise funds locally to purchase an AED.

It was agreed that any guidance developed should not be a 'one size fits all'. There should be guidance that covers a 'top-down' approach when money is made available by government and companies to purchase a large number of AEDs. Then there should also be guidance for small groups, for example charities and local parish councils, who raise funds to purchase an AED for their community, a 'bottom-up' approach.

Non-automated external defibrillator deployment issues

As mentioned above there were several other issues that were discussed during the stakeholder meeting. These included:

- Improve visibility and accessibility of existing AEDs:
  - Signposting of AEDS: it was stressed that guidelines should be followed to signpost where a defibrillator is located to its increase its visibility. Lessons could be learnt from fire prevention and location of fire extinguishers.
  - Any AED located within a building should, if possible, not be locked away.
  - Training in how to use an AED should be encouraged, especially in local communities. It should also be encouraged in schools and be part of the new health education curriculum for secondary school students. Suggestions were made that it should start earlier in primary schools. This is especially important following the announcement by the Department for Education to put an AED in every state school.
  - Training in AED use should also be mandatory in any company's first aid course, and possibly induction training.
- The moral argument:
  - There is a moral argument to consider whether AEDs should be considered like fire extinguishers; however, this needs further debate.
  - Automated external defibrillators are a critical utility and should be part of the urban infrastructure.
  - A social movement should be created that sees companies feeling pressured to help.
  - There should be no legal obligation for anyone (individual, group or company) to purchase and locate an AED in a publicly accessible location, but they should be encouraged to do so.
  - Companies should be incentivised to provide for their local community and not just the workplace. They should put funds into a local pot that would allow for the purchase of an AED for placement in the community in which they are located.
  - Good guardianship should be encouraged to keep the AED maintained.
- Increase awareness:
  - More can be done in schools about location, fundraising and awareness.
  - How to use an AED should be included in the national curriculum.
- Improve inequalities:
  - Public funds need to be made available to address health inequalities regarding OHCAs.
  - Funding should be matched between business, charities, and local and national government.
  - Local governments should be encouraged to advise any builders of local housing to also provide a publicly accessible AED as part of the scheme. It should be part of any planning application process. This is especially the case for social housing.
  - What can local councils do to support this?
  - Need to address urban residential areas; it seems that rural areas may have one in the village hall, but where is the community focus in urban areas?
- Financial:
  - There should be tax incentives for organisations that purchase AEDs, and perhaps all machines should be exempt from VAT.
  - Insurance companies should be encouraged to provide packages if the AED is to be installed outside.
  - All AEDs should be trackable. This is not only in terms of insurance purposes if stolen; it could potentially stop AEDs from being stolen in the first instance. In addition, if an AED is used it could then be located again if not returned to its cabinet. There have been instances when AEDs have been taken by ambulance staff and subsequently left at accident and emergency. If a tracker is installed it could alert the guardian that the AED has been used and indicate its location after being used. Consumables can then be replaced.
  - The cost of AEDs is a problem and pressure could be put on manufacturers to reduce this. However, the current worldwide demand for raw materials and AEDs may limit their ability to do this at the present time. The introduction of the new CellAED® (https://cellaed.io/uk) onto the market may lead to a 'price war'.

- AED manufacturers and suppliers should persuade the purchasers that they should make them publicly available and register them on The Circuit. If they do this, then assistance would be provided in maintenance, replacement of consumables, and potentially with replacement if vandalised, and assistance in replacement of old for new.

Potential future areas of research

The group that looked at future areas of research identified the following topics for consideration.

- Is it possible to optimise the location of AEDs already in place? Considerations should be given to:
    - restrictions already in place
    - can they be made available 24/7?
- Does locking a cabinet prevent an AED from being vandalised or stolen, compared to keeping them in unlocked cabinets?
- Can we quantify the delays to defibrillation by bystanders using publicly accessible defibrillators, and reasons why there are delays?
- Can we study the balance between an AED being retrieved by a bystander and a community first responder with an AED taking it to the scene?
- Areas not covered based on time, for example remote rural areas.
- Establishing the impact of deploying AEDs to residential areas.

Chapter 5 Discussion

The primary aim of this project was to develop a model that would optimise the placement of public-access AEDs in England, using mathematical modelling techniques, to maximise the likelihood that those helping an individual sustaining an OHCA would have access to an AED, improving the sufferer's chances of survival. We then proposed to assess the cost-effectiveness of optimised public-access AED placement compared to CP. The results would hopefully aid decision-makers in improving survival rates of OHCA victims, which currently are worse than one would desire. Quick defibrillation by AEDs has a high potential to improve these rates, but this has often not been realised yet in practice, as evidence from the OHCAO registry demonstrates.[1,2,18] The ERC states appropriately that 'any technology that improves the delivery of swift bystander CPR with rapid access to an AED is to be encouraged'.[117] 'It takes a system to save a life.'[148]

Although evidence supports the clinical effectiveness of public-access AEDs, there is relatively little evidence informing the optimal system configuration or most cost-effective approach.[76] Specific knowledge gaps include the effect of strategies to improve public access defibrillator use and where best to place AEDs for public access.

The ILCOR Consensus in Science and Treatment Recommendations (2020) made strong recommendation in support of the implementation of PAD programmes for patients with OHCA based on low-certainty evidence.[149] The ILCOR Scientific Statement on Public Access Defibrillation addresses several key interventions (early detection, signage, novel delivery methods, public awareness, device registration, mobile apps for AED retrieval and PAD), one being optimising the availability of AEDs, which should be considered as part of all recent PAD programmes,[77] ILCOR suggested coordinated, data-driven, regional strategies to optimise deployment of AED resources based on cardiac arrest risk and site accessibility.[142] They deemed that public-access AED programmes should prioritise deployment of new defibrillators in locations deemed to be at highest risk of the occurrence of cardiac arrest and under-served by available AEDs.

We applied our methods to historical OHCA data that covered the whole of England, served by the 11 NHS ambulance services. We used the LSOA as the proxy for neighbourhood and showed that these have heterogeneous characteristics, as defined by data from the Census and other government sources. We included both public and residential OHCAs of all ages in the analysis. We determined the current coverage of the historical OHCAs by AEDs registered with each ambulance service, and potential coverage by alternative-placement strategies: POIs, 1 km^2 grid centroid, COA centroid. We presented an optimisation technique to tackle the mathematical AED deployment problem – where to place AEDs such that the total provided coverage for OHCAs is maximised. For the 'coverage', we implemented a realistic gradual coverage function, which follows typical survival functions that depend on the TTD as defined by the MCLP. We then compared the cost-effectiveness of each strategy. Finally, a stakeholder workshop was held to discuss the results and determine a policy on where AEDs should be deployed in the future.

We have considered all OHCAs irrespective of where they have occurred. According to Ringh *et al.*,[22] the current concept of public-access AEDs is limited to including non-residential OHCAs, thereby excluding the majority of OHCAs that occur in the place of residence.[1,2,18,19]

We have modelled AED placements as static locations, and not considered personal, drone-delivered or mobile AEDs, which were outside the scope of this study.

Current situation

According to the OHCAO registry only about 6.8% of bystander-witnessed OHCAs (5.5% of all OHCAs) had a public-access defibrillator attached to them.[2] However, it is not clear whether a shock was delivered in all these cases. We have shown that the density of registered AEDs varies significantly around the country, but on average is about 1 every 4 km^2 and 1 per 1,727 people (see *Table 6*). More than 56% of the LSOAs in England were found not to have a registered AED within their boundaries. These areas were more likely to have a higher residential population density but lower workplace population density, and where a greater proportion of the population identified as being from a mixed race or non-white ethnic background.[74] They were also in areas that were more deprived. These characteristics contrasted with where OHCAs occurred more frequently.[53] These findings are not unique to England; similar findings have been observed in Scotland,[105] New Zealand,[150] the USA[151] and South Korea.[152,153] Although many AEDs are available in England, there is disparity in their current distribution, with populations at higher need having lowest access.[74] There is a social gradient in cardiovascular disease mortality, with more deprived areas experiencing higher mortality rates,[154] and cardiovascular disease is the largest cause of premature mortality in deprived areas[155] due to health inequalities. In deprived areas, people spend more time in poor health[156] and multimorbidity is more common.[157]

In a survey of persons responsible for public-access AED placement in UK it was stated that various risk assessment methods had been used to position a public-access AEDs.[158] These included areas with: (1) high footfall and public spaces; (2) high population density; (3) elderly populations; (4) high physical activity, such as sports venues; and (5) delayed ambulance response. They also said that the locations of historical OHCAs and distance from another public-access AED should be considered. Moreover, respondents suggested that areas experiencing health inequalities should be prioritised.

According to the OHCAO registry, use of a public-access defibrillator by a bystander occurs in about 6.8% of bystander-witnessed OHCAs (5.5% of all OHCAs).[2] However, we did observe that, on average in England (despite variation between the ambulance service regions), about 5.4% of OHCAs occurred within 100 m of a registered AED, 8.2% within 200 m and 38.9% within 500 m (see *Table 13*). A similar finding was observed in Copenhagen, where only 3.8% of all OHCAs had an AED applied prior to EMS arrival, but 15.1% had occurred within 100 m of an accessible AED.[159] Thus, for whatever reason, there could be a significant improvement in the use of defibrillators.

Based on the current situation, it is clear there is a disproportionate distribution of registered AEDs in England. Any future PAD programme should, therefore, give preference to areas where OHCAs are more likely to occur and that are more deprived. However, any deployment strategy must be objective and evidence-based, and data-driven, which will make it possible to identify the optimal number of and best location for outdoor AEDs.

Alternative placement

Following the assessment of current coverage, we then assessed whether alternative AED deployment strategies could improve the OHCA coverage.

Point-of-interest coverage

The POIs selected for alternative-placement coverage were based on their prominence and recognition within society, and the potential logistics it would require for the installation of an AED. Their selection was also based on previous research,[87] and following the advice of the project's co-applicants and the Steering Committee. There are over 600 potential POIs for which location information is available that could be considered for potential locations in the future. Some we deliberately did not include in the analysis, for example hospitals, airports and railway stations, where we believed, following previous campaigns, AEDs were already located. Others, like bus stops and post boxes, because of the numbers, would be expected to significantly improve coverage, but the cost involved in installing an AED in every one would be prohibitive.

Using an operational radius of 500 m, agreed with the co-applicants and Steering Committee members, the proportion of OHCAs covered by 1 of the 15 analysed POIs ranged from 7.4% to 55.1%, if we ignored the currently registered AEDs, 5.5–46.0% for OHCAs not already covered by a registered AED, and 42.2–67.0% for those covered by a registered AED or the POI (see *Table 24*). In each case the lower figure relates to state secondary schools and the higher figure to cash machines and is probably related to the number of these POIs, 3453 and 38,890, respectively. Other studies have found various building types improve OHCA coverage, depending on the setting. These include post collection boxes,[86,87] phone boxes,[21,87] bus stops,[87] schools,[87,89] community centres,[89] coffee shops and banks,[72] and convenience stores.[95] A recent systematic review identified offices, schools and sports facilities as the top three building types.[97] Although these studies have identified building types, what is evident is that they should be prominent and easily identified.[160]

The coverage figures assume that the AED would be available 24/7 at these POIs. If, however, they were available only when the POI was deemed to be open, then the loss of coverage was significant (see *Table 25*). Similar coverage losses, because of inaccessibility at certain times (e.g. evening, night-time and weekends), have been observed, for example, in the UK,[54] Australia,[21] Canada[41,72] and Denmark.[57,104,161] Malta-Hansen *et al.*[57] concluded that not only strategic placement of AEDs but also uninterrupted accessibility warrant attention if PAD is to improve survival after OHCA.

Therefore, as stated by the RCUK, 'when buying one or more AEDs, consideration should be given to making them available 24/7 for full public access'.[162] This is also the policy of the ERC[16] and ILCOR.[142] A recent systematic review of studies also concluded that the survival rate of OHCA patients may be improved with increased accessibility of AEDs in the area in which the OHCA occurred, which can be measured by the density, distance and time of access to AEDs.[88]

Grid coverage

Deploying AEDs based on a 1 km^2 grid centroid had a significant impact on the OHCA coverage, with 78.8% of all OHCAs occurring within 500 m of a centroid (28.5% within 300 m) (see *Table 28*). We also showed that at an OHCA–AED distance of about 700 m the grid-based strategy would cover all OHCAs (see *Figure 10*). In Paris, using various distances between AEDs, coverage was found to follow an exponential decay model.[73] Increasing the number of AEDs deployed in a grid-based distribution decreased the OHCA–AED distance up to around 350 AEDs, after which additional AEDs did not have a significant impact in reducing the distance. In a systematic review, studies that examined a grid-based system of deployment showed a threefold increase in the use of an AED by a bystander, and 30-day survival doubled.[97] However, the distance in the studies reviewed ranged from 200 m to 2 km.

Although coverage is significant with a grid-based approach, placing an AED at the centre of each of the over 170,000 1 km^2 grids would not be cost-effective, and some would be placed in the middle of nowhere, at the top of large hills, or in the middle of large bodies of water. Therefore, a strategic approach would be required, and probably best incorporated in the optimisation approach.

Census output area coverage

Out-of-hospital cardiac arrest coverage, if an AED was placed at the COA centroid, was significantly lower than that with a 1 km^2 grid-based deployment. Approximately 23.4% of OHCAs were covered at 500 m (11.7% at 300 m) (see *Table 29*). This is surprising because the centroids used were population-weighted by the ONS. Even though there are similar numbers of COAs and 1 km^2 grids, the nature of the shape and size of COAs means that in certain areas of the country if an AED was placed at the centroid, it would not cover an OHCA that occurs on its periphery. Nevertheless, coverage in rural COAs (at 500 m), which are generally larger in area, was greater (38%) compared to urban areas (21%), possibly because rural OHCAs tend to occur in villages, etc., that are the population centre for that area. In rural areas fewer OHCAs would be expected on the COA periphery because they are more remote and less densely populated.

Nevertheless, the COA could be used to assess the potential risk of OHCAs for an area being considered for AED deployment. The COA, or similar, has been used elsewhere to identify areas of high risk for OHCAs.[68,147,163–167] Much of the risk assessment information (see *Current situation*) considered essential for determining the best place to position a public-access AED is available from the Census. In addition, OHCA risk at this level (not all of the country) can be obtained from the OHCAO registry team at the University of Warwick. Previous work has identified parts of the country as 'hot spots' for OHCA incidence.[53] Plans are progressing to update this analysis on an annual basis, depending on the availability and accuracy of information provided by the ambulance services to the OHCAO registry.

Optimisation coverage

A spatiotemporal optimisation model was able to identify evenly spaced locations 1 km^2 apart throughout each ambulance service region that can reverse the coverage loss associated with the limited temporal availabilities of existing AEDs and if deploying additional AEDs in various POIs.

Figure 12 shows the proportions of covered OHCAs in the West Midlands based on AED placement according to the optimised approach and the POI-based approach. On one hand, it is good to see that existing AEDs can cover 66.7% of historical OHCA locations. However, even a relatively small number of optimally placed AEDs would lead to substantial gains in OHCA coverage over POI-based AED placement. For example, placing AEDs in all secondary schools in the West Midlands (n = 424) leads to a 6.5% relative increase in OHCA coverage, but placing the same number of AEDs in optimised locations instead leads to fourfold higher gains in coverage. Similar results are seen for the other POIs.

Optimisation modelling has been proved to effectively determine optimal sites for the deployment of AEDs, and regularly out-performed population-guided strategies. The work was developed in Toronto, where business types were identified to optimally site any future AEDs purchased in the city and its environs.[41,71,72,100] This method was applied to data from Copenhagen, where similar gains in OHCA coverage were observed, suggesting that the benefits of optimising public-access AED placements can be generalised to new settings to improve OHCA response and public-access AED programmes worldwide.[102–104] Furthermore, the method can incorporate other factors, such as deprivation indices, population density, etc. into the model to identify areas in greatest need.[105]

Other studies have developed similar optimisation models based on the MCLP,[106,107,168,169] while others have developed location-allocation models[81,96,108–110] to develop a strategy for deploying AEDs. All these models worked better than a guidelines-based and simple grid-based and landmark-based strategies.

Optimisation can identify the area/grid to deploy an additional AED that would improve the coverage given a fixed number of AEDs to deploy. It can also identify the most ideal POI within the area/grid to maximise the improved coverage. However, any deployment would still require someone with local knowledge to take responsibility to get the AED installed and negotiate with POI owners and others to get permission to install the AED and get them to promise to act as guardian to the AED.

Cost-effectiveness

Findings

The costs and benefits associated with public AED placement in POIs was examined through an economic evaluation (WP3). This was based on a purpose-built decision-analytic model and took the form of cost-effectiveness and cost-utility analyses, with findings reported as additional cost per QALY and additional cost per LYG.

In line with recent studies on the broader topic[59,126] the constructed model used a hybrid structure consisting of a decision tree (short-term part) and a Markov model (long-term path), over a 10-year time horizon starting from OHCA occurrence. To model events as realistically as possible, the model branches associated with alternative defibrillator placement and CP were identical in their representation of possible pathways of care and outcomes, but differed in probabilities of events occurring, most notably the probabilities of an AED being available and being used when available, given the compared deployment options. Various scenarios were considered, including different distances and availability during a day. The cost of additional defibrillators needed to implement the assessed alternative-deployment strategies was calculated by considering number of defibrillators needed and their associated purchase, installation, and maintenance costs, and it was added to each of the compared alternative placements. Deterministic and probabilistic analyses were carried out to assess the impact of alternative scenarios, assumptions and parameter values on the base-case study findings, and value-of-information analysis (EVPI) was performed to quantify the expected opportunity loss due to making a decision, given current uncertainty (as opposed to 'perfect' information).

Results showed that all placement scenarios were associated with a greater expected total cost compared to current AED placement, for a largely modest increase in QALYs and LYG. It is logical to think that instalment of more defibrillators will improve outcomes automatically and proportionally. However, the relationship between improved availability and outcomes (especially long-term outcomes) is complex and is affected by different parameters. While improved coverage raises the likelihood of an AED being available (as compared to CP), unless an AED is used (and in many cases even if it used) and unless the number of additional AEDs deliver the greatest possible improvement in terms of coverage, more AEDs do not necessarily equate to improved health benefits.

Compared to CP, all alternative POI-based deployments considered here resulted in ICER values above £30,000 per QALY, which is over the upper bound of the £20,000–30,000 per QALY range that is often seen as the threshold considered for decision-making in health care.[123,146] The most cost-effective POI deployment was halls and community centres, with an ICER of £32,418 per QALY (£18,893 per LYG). While such an ICER value may not be necessarily prohibitive[123] it is expected that at this 'willingness to pay' level, decision-makers will expect to see an increasingly stronger case for considering the programme as an effective use of public resources.

The divergent results pointing to improved 'effectiveness' but relatively high ICER values highlight the fact that, while additional AEDs improve availability and coverage, these come at an increased cost that results in ICERs above £30,000 per QALY. This is not a rare finding (indeed a situation where an intervention is effective but not cost-effective is not uncommon) and underlines the importance of conducting an economic evaluation to identify whether an assessed intervention represents 'value for money'.

Existing literature on cost-effectiveness of public-access defibrillators

An increasing interest in ensuring that defibrillator provision is effective and represents value for money has given rise to a full and partial economic evaluation on the topic.[50,59,100,170–173] Perhaps unsurprisingly, there is considerable heterogeneity amongst studies carried out in different countries and assessing a range of AED arrangements (e.g. static AEDs, provision of portable AEDs carried by lay bystanders, police personnel or firefighters etc.) against different comparators and schemes.[33,59] Indicatively, these include evaluations carried out to assess whether the development of unmanned aerial vehicle (drone) networks delivering early defibrillation is effective and cost-effective (in North Carolina and Germany, respectively),[170,171] as well as studies looking into the cost-effectiveness of deploying AEDs in vehicles [e.g. passenger aircrafts or specific locations (e.g. casinos, transportation hubs)], with or without training bystanders.[38,90,172,174,175]

The study by Moran *et al.*[59] in Ireland is relatable to the study. The authors examined the clinical and cost-effectiveness of an AED programme based on mandatory provision of static AEDs in designated building types in Ireland, compared to CP involving undirected voluntary AED provision. Similarly to the present study, the authors developed a hybrid model (a decision tree followed by the Markov model) that follows an annual cohort of individuals who experienced an OHCA over their lifetime. Six different configurations were assessed (based on static AEDs in building types with different incidence of OHCA to a comprehensive scheme outlined in proposed Irish legislation). Cost-effectiveness was assessed in terms of additional costs (or cost savings) and benefits (in QALYs). Key states in the model included the patient being brought to hospital alive, surviving hospital admission, surviving hospital discharge, and being discharged with a different CPC score. Unlike the present study, the analysis by Moran *et al.*[59] assumed that an average of two staff members would receive training in each designated centre, and included training in the cost calculations. The authors found that, while all the PAD programmes appeared to lead to improved OHCA survival, none were considered cost-effective using conventional willingness-to-pay thresholds (defined as €45,000 per QALY). The most cost-effective comparator was AED placement in locations, such as public transport stations, medical practices, entertainment venues, schools and fitness facilities, yet it was associated with an ICER in excess of €95,000 per QALY. However, given the differences between the study by Moran *et al.* and the present study (e.g. in the compared schemes and their components, numbers of AEDs currently deployed and key parameters), comparisons between these studies are precarious.

In this study, we did not consider the economic impact of relocating some or all of the currently registered AEDs. Relocation is uncommon and not normally standard practice. This is understandable considering that most AEDs have been purchased and installed by local groups who raised the required funds, for their community, and would be reluctant to relocate them for obvious reasons. Nevertheless, a number of studies have shown that relocation can improve coverage and be cost-effective. In Toronto, Chan and colleagues[101] showed that optimally relocating all existing AEDs (n = 1669) would increase coverage from 12.8% to 28.4%. To achieve this additional coverage would require an additional 900 optimised AEDs if the existing AEDs were not moved. In Switzerland, Aeby *et al.*[80] found that 17 out of 633 AEDs could be relocated without reducing coverage, thus reducing the number of new AEDs that would be required. Again, in Switzerland, Tierney and colleagues[108] developed a FLM that allowed for the relocation of existing AEDs. It increased OHCA coverage, even in rural areas, and decreased the distance between an OHCA and the nearest AED, with a significant saving of financial resources. Finally, Leung *et al.*[105] found in Scotland that optimally relocating existing AEDs achieved similar OHCA coverage levels to that of doubling the total number of existing AEDs (1532 to 3064).

Stakeholder meeting

The issues raised at the stakeholder meeting have been previously mentioned in a systematic literature review on the barriers and facilitators to PAD,[23] in the recent ILCOR statement on optimising outcomes after OHCA with innovative approaches to PAD[142] and in a recent survey of stakeholders involved in PAD placement in the UK.[158]

It was agreed that the current distribution of registered public-access AEDs was suboptimal. The analysis of the neighbourhood characteristics of where OHCAs occurred (see *Out-of-hospital cardiac arrest*) and currently registered AEDs are located (see *Automated external defibrillators*) supports this. Notably, the incidence of OHCAs increased (see *Figure 3*) with increasing measures of deprivation, whereas the number of AEDs decreased (see *Figure 4*). Other health inequalities should also be considered, as highlighted by Lac *et al.*[158] (see *Current situation*).

Public-access AEDs should be placed outside buildings and accessible 24/7. Numerous studies have shown a significant coverage loss when an AED is locked away, most notably evening, night-time and at weekends. So, if an OHCA occurred at any of these times its likelihood of being treated by a public-access AED is decreased, with the subsequent decrease in chance of survival.

Automated external defibrillator signage is important to help a bystander identify the location of an AED. A survey of the public carried out in 2015 helped in the production of a new improved location sign, and associated information poster, for use in the UK.[176] However, despite this, a survey in a major UK city the following year observed only 33% of AEDs had adequate signage, and that only 7.5% had signage at a distance from the AED to indicate its location.[177] In addition, a survey at London's mainline railway stations observed no AEDs were mounted in prominent, central positions on station concourses; signage was poor; and no station had any direction signs guiding people to an AED.[160] The recent ILCOR statement makes seven policy suggestions with regard to AED signage to improve PAD implementation.[142]

The method to deploy new public-access AEDs was discussed extensively, with the POI-based (27%) and optimisation (58%) models the most popular. The benefits of these have been discussed above.

Various OHCA–AED distances were suggested for consideration for optimal deployment. However, it was agreed to use 500 m, which is the typical maximum range that UK ambulance services currently use for directing bystanders to a public-access AEDs in the event of an OHCA.[54,178]

All these points also reiterate what the current guidelines of the RCUK, ERC, AHA and ILCOR state should be the norm.

Limitations

Solving the public-access AED problem poses many unique challenges. The methodology used addresses several assumptions and other issues related to prior approaches to solve this reality-based facility location problem. Intuitively, the research has its limitations:

- We included AEDs that were registered with ambulance services as of the end of 2019. However, these databases were not maintained and not kept up to date. Thus, some AEDs might not have been in operation or might have been taken out of service, which would mean we have overestimated coverage. The Circuit is ensuring that all AEDs are claimed by their guardians, who then state whether the machine is still operational. The Circuit is also informed when an AED is used and out of service until it is put back in its place. It has only recently obtained AED details from every ambulance service. Once it is complete we can re-run the analysis on a regular basis.
- We have assumed various temporal availability of AEDs according to when the historical OHCAs occurred. We assumed that registered AEDs were accessible only during normal working hours and any AED placed at one of the POIs was accessible during the 'normal' opening hours at that POI. For the registered AEDs some would certainly be accessible 24/7, while others would not; however, that information was not available. It is hoped that The Circuit will ensure that such information is stored on the database, which will help ambulance dispatchers during 999 calls.

- Allocating AEDs to infeasible locations (location of deployed AEDs should only be considered as a guideline). Mathematically speaking, an effective approach would be to run the optimisation model on a grid-based system, then identify a POI within that grid to deploy the AED. This new AED should then be set as 'fixed'. Then if someone else wants to deploy a new AED within that area, the model should be run again.
- Historical OHCAs: we have assumed that the historical distribution of OHCAs is representative for future incidences. It is impossible to predict exactly where and when future OHCAs will occur, simply by the fact that they are defined as sudden. However, historical OHCA incidence has been found to be spatially stable over time at the neighbourhood level, as it is heavily tied to neighbourhood population density and characteristics, and activities of individuals. It has been shown that the geographical distribution and number of OHCAs remains steady over time, with high-risk neighbourhoods tending to remain high risk.[100,163] This fact supports focusing public health resources in those areas to increase the efficiency of scarce AED resources and improve the long-term impact of health-related interventions in the community. The OHCAO registry has also received four more years' data on OHCAs in England (2020–3), amounting to about 130,000 additional cases, upon which we can update the analysis once it has been geocoded. The registry has also received data from Wales upon which we can apply the models.
- We have considered walking distance in the assessment of coverage rather walking time, assuming that anyone who goes to collect an AED walks at the same speed, which may not be the case. However, it is still important to consider walking distance, rather than straight-line distance, in this location problem because seconds matter when critical care is needed for OHCA victims.
- We have performed the analysis using 500 m as the OHCA–AED distance. Other studies have used 100, 200 or 300 m. We used 500 m because this is the typical maximum range that ambulance services in the UK use for directing bystanders to a public-access AED in OHCA. Further analyses could be more restrictive on the distance that can be walked.
- Due to the lack of available data at the time of the analysis, a comparison of a placement based on the optimisation model against CP through the analytic model was not possible. These data will soon be available, and we plan to update this analysis when they are.
- The economic analysis was limited by the availability of relevant data (see *Work package 3: cost-effectiveness* for details). In cases where data were unavailable (e.g. health-related quality of life for a patient suffering cardiac arrest), values were specified using plausible assumptions and drawing, where possible, on existing literature.
- Due to lack of available probability estimates, patients entering the long-term (Markov model) part of the economic model were assumed to either remain alive in the same functional state or die, using different probabilities for the first and subsequent years. This effectively assumes that patients cannot move to another functional status (i.e. do not improve or deteriorate) in each cycle.
- In the economic analysis we have not considered the cost impacts of relocating existing AEDs to more optimal locations or making them accessible at all times. Previous studies have shown that it can be made cost-effective and potentially improve coverage.[80,100,105,108]

Chapter 6 Conclusions

Automated external defibrillators stand as vital life-saving devices for individuals experiencing an OHCA. To maximise their effectiveness, it is imperative to strategically position AEDs in public areas to ensure easy accessibility and utilisation by bystanders. We have developed a data-centric approach aimed at aiding the decision-making process for the placement of public-access AEDs. This approach harnesses optimisation techniques and statistical methods to guide these critical location choices. We applied the methodology to real data from England.

We have developed a data-driven framework to support public-access AED location decisions, using optimisation and statistical models. Results demonstrate 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 improved coverage but were also more costly, resulting in ICERs above £30,000 per additional QALY.

Chapter 7 Consideration for deployment and future research

Deployment

In order to optimise impact:

- AEDs should be accessible 24/7:
    - The authors are working with the RCUK to update their document 'A Guide to AEDs', which will emphasise the accessibility of AEDs.
- Future AED placement should consider location of current AEDs, risk of cardiac arrest and the reduction of health inequalities:
    - We are working closely with the BHF, RCUK and others to develop an online platform to identify areas of high OHCA risk which lack an AED, to reduce health inequalities.
- Optimisation models provide data-driven guidance on where to place future AEDs to maximise benefit:
    - We are working closely with colleagues from the Universities of Edinburgh and Toronto to develop a web-based system to identify potential locations.

Future research

Relevant questions for future research include:

- How does the deployment of AEDs in rural areas, where ambulance response times are greater, improve OHCA coverage?
- What impact will The Circuit have on OHCA outcomes?
    - We are developing a research plan to assess the impact of The Circuit on the distribution of AEDs around the country to ensure there is no inequality of availability and access, and on the use of publicly accessible AEDs and potential impact on survival.
- What are the advantages and disadvantages of locking an AED in a cabinet?
    - Vandalism and theft of an AED could impact on their availability and use, a locked cabinet being hypothesised to reduce the risk. We are working with the BHF to assess the potential impact of this on OHCA survival.
- What interventions are effective at improving AED use where one is present?
    - We are working with various groups involved in training to publicise the benefits of AEDs and dismiss the fears people have about using them.

- What would the impact be of optimally deploying AEDs to residential areas?
    - There is no policy to put AEDs in residential areas despite 80% of OHCAs occurring in place of residence. We are planning to explore this in more detail.
- What are the incremental costs and benefits (in QALYs) of comparison of an AED placement based on the optimisation model against CP?

Chapter 8 Impact

The work in this project has already had an impact on the deployment of AEDs in England.

Automated external defibrillators in schools

During the conduct of the study, opportunities were taken to work with the Department for Education's (DfE) modelling and subsequent decision to install an AED in every school. Data provided from the project informed the DfE recommendation of making AEDs available 24/7 and the central purchasing of external AED cabinets (www.gov.uk/government/news/every-school-will-have-a-life-saving-defibrillator-by-2223).

Department of Health and Social Care automated external defibrillator programme

We worked closely with the Department for Health and Social Care, which was allocated £1M to purchase AEDs, to identify areas with greatest need for an AED to provide an evidence-driven approach to prioritisation of AED requests (www.gov.uk/government/news/number-of-defibrillators-to-be-increased-with-new-funding).

United Kingdom bank

We worked closely with a UK bank which purchased 65 AEDs. The bank asked us to identify areas in England where OHCA incidence was high and the level of deprivation greatest (as indicated by the index of deprivation) but there was no registered AED.

Updated national guidance

Investigators (TB, GDP, CD) are providing input into the revision of the RCUK's 'A Guide to AEDs' guidance document.

Resuscitation Council United Kingdom

We worked with colleagues at RCUK to provide evidence to the All Party Parliamentary Group dedicated to investigating and improving public access to AEDs (House of Commons – Register of All-Party Parliamentary Groups as at 5 April 2023: Defibrillators).

Evidence is also being provided to RCUK to support activities on Restart a Heart Day on 16 October 2023.

Nonprofit organisation

We are working with a nonprofit organisation which wishes to deploy a significant number of AEDs in communities, and to identify ideal locations within them to deploy them.

PADMap project

We are also working closely with colleagues in Scotland and Canada to apply the methodology used in this project to develop a web-based application to map PADs that will help identify locations for new AEDs being purchased.

Additional information

Equality, diversity and inclusion

Warwick Medical School and the University of Warwick are committed to social inclusion, which is about removing economic, social and cultural barriers that have prevented people from working, studying and succeeding:

- Social Inclusion Group (warwick.ac.uk).
- Equality, Diversity and Inclusion and Athena SWAN (warwick.ac.uk).
- Athena SWAN and Equality, Diversity and Inclusion at WMS (warwick.ac.uk).

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South-Western Ambulance Service NHS Trust

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University of Warwick

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- Mr Scott Booth, OHCAO Registry Database Officer.
- Mr Scott Regan, Senior Project Officer.
- Mrs Kath Starr, Senior Project Officer.
- Dr Chen Ji, Associate Professor in Clinical Trial Statistics.
- Professor Ranjit Lall, Professor of Clinical Trials.
- Manoj Nanji, Research Development Officer.
- Deborah Owen, Research Support Manager.
- Rachel Gower, Data Protection Officer.

Study Steering Committee

- Professor Matthew Cooke, Former Regional Clinical Director, Emergency Care Improvement Programme, NHS Improvement.
- David Bywater, Consultant Paramedic, Scottish Ambulance Service.
- Mr Ian Trueman, Lecturer, University of Lincoln.
- Steve Irving, Executive Officer, Association of Ambulance Chief Executives.
- Dr Paul Brindley, Lecturer, University of Sheffield.
- Me Neil Morris, PPI.
- Mrs Rosemary Wilson, PPI.

Sponsor representative

- Dr Sarah Pountain, University Hospitals Birmingham NHS Foundation Trust.
- Mrs Rachel Ward, University Hospitals Birmingham NHS Foundation Trust.

Contributions of authors

Terry P Brown (https://orcid.org/0000-0001-8623-5350) (Assistant Professor Epidemiology) was co-chief investigator of the PAD-optimisation study. He led the team of co-applicants, researchers and support staff who conceived and designed the study. He led the data-collection analysis and interpretation of the study findings. He led drafting the report and revised it critically for important intellectual content.

Lazaros Andronis (https://orcid.org/0000-0001-7998-7431) (Reader in Health Economics) provided oversight of all aspects of the cost-effectiveness analysis, including its design, conduct, analysis and reporting.

Asmaa El-Banna (Health Economist) was involved in development of the economics models and initial analysis of data.

Benjamin KH Leung (https://orcid.org/0000-0001-9972-3433) (Clinical Data Analyst) led the data analysis in relation to the optimisation process and interpretation of the study findings. He assisted in drafting the report and revised it critically for important intellectual content.

Theodoros Arvanitis (https://orcid.org/0000-0001-5473-135X) (Professor of Electronic, Electrical and Systems Engineering) was involved in interpretation of data and revised the work critically for important intellectual content.

Charles Deakin (https://orcid.org/0000-0002-2565-9771) (Consultant in Cardiac Anaesthesia and Intensive Care) was involved in interpretation of data and revised the work critically for important intellectual content.

Aloysius N Siriwardena (https://orcid.org/0000-0003-2484-8201) (Professor of Primary and Pre-Hospital Health Care) was involved in interpretation of data and revised the work critically for important intellectual content.

John Long (https://orcid.org/0000-0003-0674-2972) (Patient and Public Involvement) was involved in the design of the study and revised the work critically for important intellectual content.

Gareth Clegg (https://orcid.org/0000-0002-4314-611X) (Clinical Senior Lecturer and Honorary Consultant in Emergency Medicine) was involved in interpretation of data and revised the work critically for important intellectual content.

Steven Brooks (https://orcid.org/0000-0002-4592-4974) (Associate Professor in Emergency Medicine) was involved in interpretation of data and revised the work critically for important intellectual content.

Timothy CY Chan (https://orcid.org/0000-0002-4128-1692) (Professor in Industrial Engineering) was involved in interpretation of data and revised the work critically for important intellectual content.

Steve Irving (https://orcid.org/0009-0009-9665-9961) (Executive Officer, Association of Ambulance Chief Executives) was involved in interpretation of data and revised the work critically for important intellectual content.

Louise Walker (https://orcid.org/0000-0003-4712-8303) (Ambulance Education Training and Engagement Lead) was involved in data collection and interpretation of data and revised the work critically for important intellectual content.

Craig Mortimer (https://orcid.org/0000-0001-6989-2244) (Research Manager, SECAmb) was involved in data collection and interpretation of data and revised the work critically for important intellectual content.

Sandra Igbodo (https://orcid.org/0009-0001-8290-0912) (Research Support Manager, NWAS) was involved in data collection and interpretation of data and revised the work critically for important intellectual content.

Gavin D Perkins (https://orcid.org/0000-0003-3027-7548) (Professor of Critical Care Medicine) was co-chief investigator of the PAD-optimisation study. He led the team of co-applicants, researchers and support staff who conceived and designed the study. He contributed to interpretation of the study findings, assisted in drafting the report and revised it critically for important intellectual content.

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Patient data statement

This work uses data collected by the NHS as part of their care and support. Using patient data is vital to improve health and care for everyone. There is huge potential to make better use of information from people's patient records, to understand more about disease, develop new treatments, monitor safety, and plan NHS services. Patient data should be kept safe and secure, to protect everyone's privacy, and it's important that there are safeguards to make sure that it is stored and used responsibly. Everyone should be able to find out about how patient data are used. #datasaveslives You can find out more about the background to this citation here: https://understandingpatientdata.org.uk/data-citation.

Data-sharing statement

All data requests should be submitted to the corresponding author for consideration. Access to available anonymised data may be granted following review.

Ethics statement

The project 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).

Information governance statement

The University of Warwick is committed to handling all personal information in line with the UK Data Protection Act (2018) and the General Data Protection Regulation (EU GDPR) 2016/679. Further information about the University of Warwick's policies and procedures can be found at Information Governance – University of Warwick (https://warwick.ac.uk/services/gov/).

Publications

Brown TP. *Where Should PADs be Placed*? Resuscitation Council UK Annual Conference, 30 November -1 December, Vox Conference Centre, NEC, Birmingham. 2022.

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Appendix 1 Ambulance service AED operational radii; POI numbers and hours of operation

TABLE 32 Ambulance service public-access AED operational radii

- EEAS: 400 m
- EMAS: 500 m (with some being 600 m)
- IOWAS: 200 m
- LAS: 100 m
- NEAS: 500 m
- NWAS: 200 m
- SCAS: 400 m
- SECAmb: 400 m
- SWAST: 200 m
- WMAS: 200 m
- YAS: 600 m

Source: Deakin *et al.*[54]

TABLE 33 List of POIs for AED locations used in analysis, and numbers in England according to OS[118]

POI code	Description	Number of POIs
1020034	Pubs, bars and inns	37,828
2090138	Banks and building societies	8226
2090141	Cash machines	38,890
4240293	Gyms, sports halls and leisure centres	17,675
5280364	Chemists and pharmacies	11,541
5280368	Dental surgeries	8677
5280369	Doctors' surgeries	8621
5280373	Nursing and residential care homes	18,616
5310375	State first, primary and infant schools	16,653
5310379	Broad age range and state secondary schools	3453
6340456	Halls and community centres	17,604
6340459	Places of worship	41,265
9470819	Supermarket chains	6429
9480763	Post offices	8123

TABLE 34 Hours of operation of POIs used to calculate coverage of OHCA

- Public houses: 11.00–23.00 Monday–Saturday, 11.00–22.30 Sunday.
- Post office: 09.00–17.00 Monday–Friday, 09.00–13.00 Saturdays.
- Places of worship: 09.00–17.00 every day.
- Chemists: 09.00–17.30 Monday–Friday, 09.00–13.00 Saturdays; some will open on a Sunday and for emergency purposes, but this was not considered.
- Dentists: 09.00–17.00 Monday–Friday.
- General practitioners: 09.00–18.00 Monday–Friday; there will be out-of-hours service, but these would probably not make any AED available.
- Automatic teller machine: 24/7; assumed to be placed on wall next to automatic teller machine.
- Banks and building societies: 09.30–16.30 Monday–Friday; closed Saturday/Sunday and bank holidays.
- Care homes: 24/7; assumed member of staff available at all times.
- Community halls: 24/7; AED assumed to be located on outside wall of building.
- Leisure centres: 08.00–22.00 Monday–Friday, 08.00–18.00 Saturday/Sunday.
- Supermarkets: 08.00–22.00 Monday–Saturday, 10.00–16.00 Sunday.
- Primary and secondary schools: 08.30–16.00 Monday–Friday; term dates, e.g. 5/9–21/10, 31/10–16/12, 3/1–17/2, 27/2–31/3, 17/4–26/5, 5/6–25/7.

Appendix 2 Data used in cost-effectiveness analysis

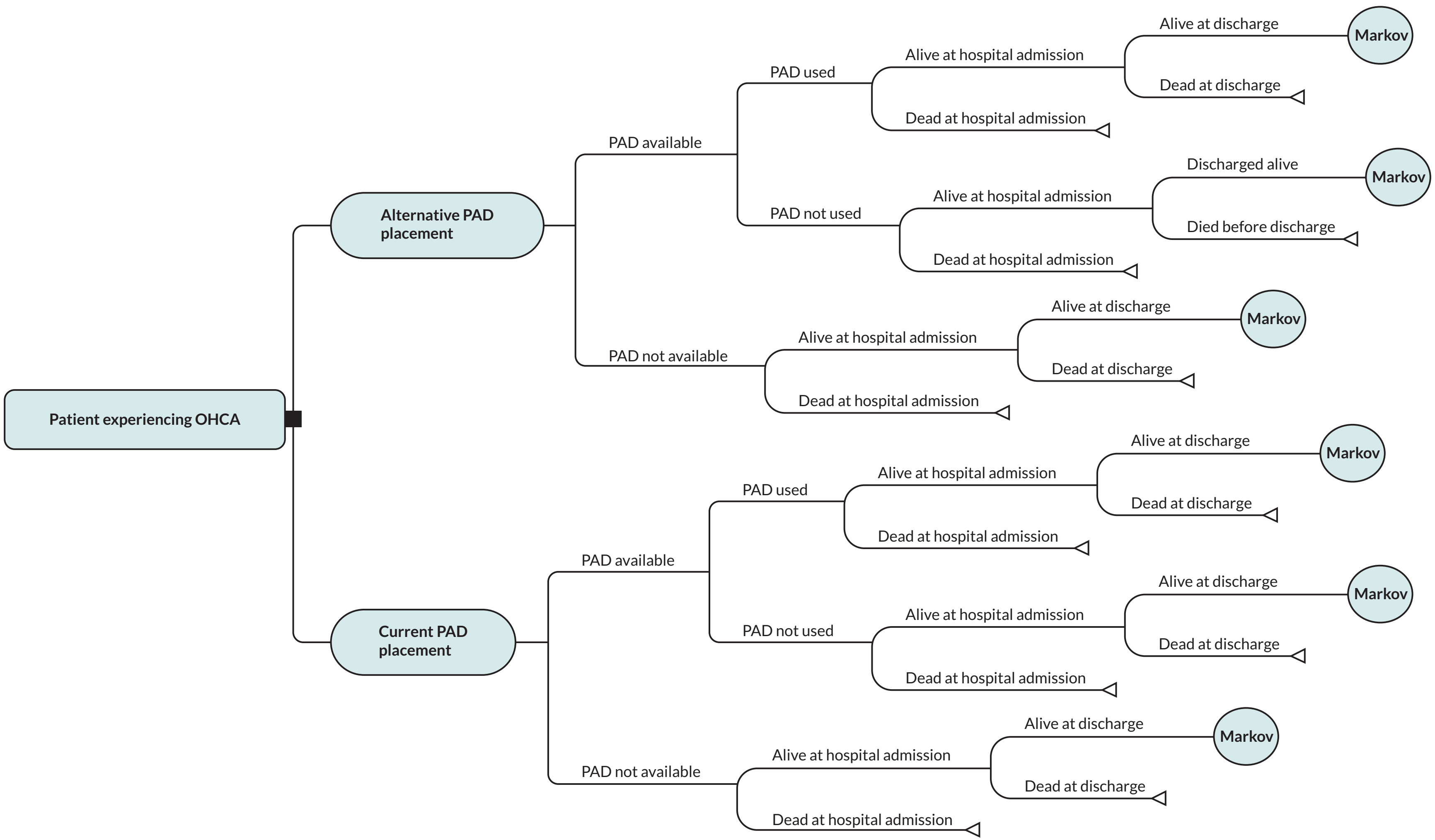

FIGURE 18 Cost-effectiveness decision model (short-term part).

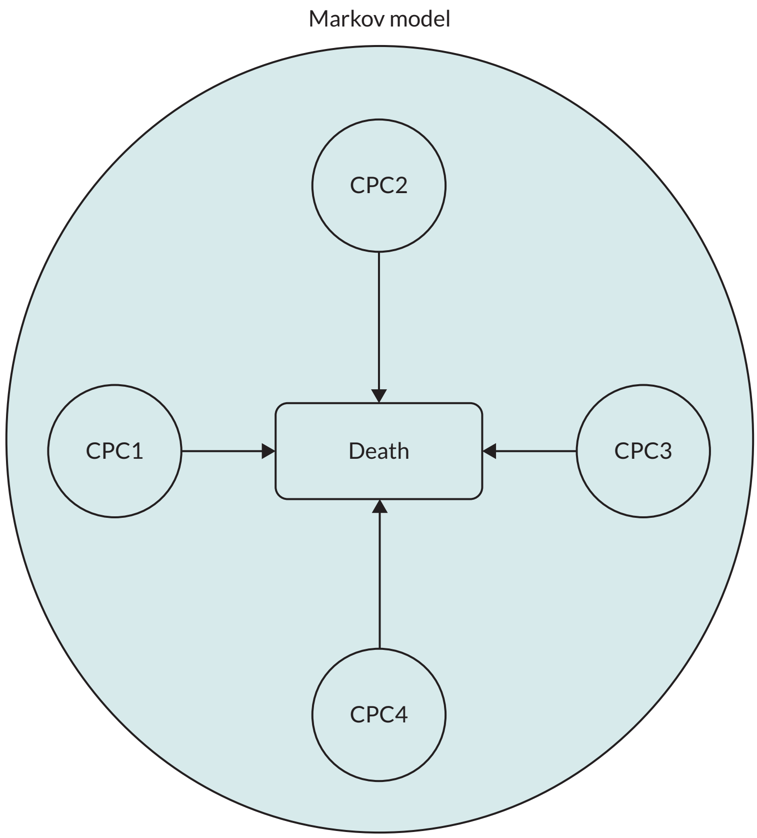

FIGURE 19 Cost-effectiveness decision model (long-term part).

TABLE 35 Probability of an AED being available, and number of AEDs needed for each assessed alternative placement

	Base-case analysis[a]	
Alternative placement (landmarks)	**Probability of AED available**	**No. of additional AEDs required**
Banks and building societies	0.154	1099
Cash machines	0.594	22,584
Chemists and pharmacies	0.200	4548
Dental surgeries	0.171	2431
Doctors' surgeries	0.174	2518
State first, primary and infant schools	0.182	3983
Gyms, sports halls and leisure centres	0.270	8161
Halls and community centres	0.413	11,174
Nursing and residential care homes	0.443	13,286
Place of worship	0.285	12,407
Post office	0.182	3052
Public houses, bars and inns	0.303	12,468
State secondary schools	0.149	774
Supermarket chains	0.217	4182

a Base-case analysis: probability of coverage calculated by accounting for the existence of already installed AEDs; based on actual (i.e. not 24/7) availability of AED; for distance of 500 m between OHCA and AED.

TABLE 36 Parameter probabilities used in the model

Variable (event or health state)	Probability value
For short-term part of model	
AED is available given current AED availability	0.142[a]
AED being available given AED availability under alternative placement	0.413[a]
AED being used if AED is available	0.144[2]
Patient arrives at hospital alive given that AED was used	0.247[2]
Patient arrives at hospital alive given that AED was not used	0.198[2]
Patient is discharged from hospital alive given that AED was used	0.443[2]
Patient is discharged from hospital alive given that AED was not used	0.315[2]
Patient is classified as CPC1 at hospital discharge	0.667[128]
Patient is classified as CPC2 at hospital discharge	0.121[128]
Patient is classified as CPC3 at hospital discharge	0.152[128]
Patient is classified as CPC4 at hospital discharge	0.061[128]
Patient in state CPC1 dies during the first year after discharge	0.086[129]
Patient in state CPC2 dies during the first year after discharge	0.233[129]
Patient in state CPC3 dies during the first year after discharge	0.361[129]
Patient in state CPC4 dies during the first year after discharge	0.720[129]
Patient in state CPC1 dies during subsequent years	0.051[129]
Patient in state CPC2 dies during subsequent years	0.080[129]
Patient in state CPC3 dies during subsequent years	0.081[129]
Patient in state CPC4 dies during subsequent years	0.071[129]

a Current study.

Note

For illustration purposes, this table contains the probability of an AED being available under deployment in halls and community centres. This value is specific to each alternative placement. See *Table 35* for a list of probabilities of an AED being available for all compared alternative placement.

TABLE 37 Costs and resource use inputs used in the model

Resource use category	Unit cost[a]	Source
Acquisition cost of AED unit	839.53	Literature/personal communication[179]
Replacement AED pads	22.14	Literature/personal communication[179]
Replacement AED batteries	87.60	Literature/personal communication[179]
Replacement AED preparation pack	12.82	Literature/personal communication[179]
Indoor lockable alarmed cabinet	215.53	Literature/personal communication[179]
Initial installation	18.00	Literature/personal communication[179]
Cost of replacing pads and batteries	9.00	Literature/personal communication[179]
EMS care	367.07	Literature[131]
Cost of in-hospital post cardiac arrest care if patient is discharged alive	42,418.58	Literature[128]
Cost of in-hospital post cardiac arrest care if patient dies before discharge	15,604.08	Literature[128]
Cost of emergency care, patient dead on arrival	718.00	Literature[132]
Cost of post-discharge care (CPC 1 or 2)	3626.00	Literature[133]
Cost of post-discharge care (CPC 3 or 4)	47,029.00	Literature[133]

a Unit cost is given in 2019–20 prices in Great British pounds (GBP).

TABLE 38 Utility scores for different health states used in the model

Variable (health state)	Utility value	Source
Cardiac arrest	0.000	Assumption
Deceased	0.000	Literature[180]
Patient receiving emergency care	0.000	Assumption
Patient treated in hospital	0.269	Assumption[a]
Patient discharged from hospital	0.538	Literature[130]
Patient classified as CPC1, first year after discharge	0.670	Literature[126,181]
Patient classified as CPC2, first year after discharge	0.390	Literature[126,181]
Patient classified as CPC3, first year after discharge	0.220	Literature[126,181]
Patient classified as CPC4, first year after discharge	0.000	Literature[126,181]
Patient classified as CPC1, subsequent years	0.770	Literature[126,181]
Patient classified as CPC2, subsequent years	0.490	Literature[126,181]
Patient classified as CPC3, subsequent years	0.320	Literature[126,181]
Patient classified as CPC4, subsequent years	0.000	Literature[126,181]

a Based on mid-point between patient receiving emergency care and patient discharged from hospital.

TABLE 39 Parameters and distributions used in PSA

	Base-case point estimate	Distribution family	Parameter a	Parameter b
AED is available given current AED availability	0.142	Beta	20,842	126,436
AED being available given AED availability under alternative placement	0.413	Beta	60,885	86,393
AED being used if an AED is available	0.144	Beta	317	1879
Patient arrives at hospital alive given that AED was used	0.247	Beta	244	742
Patient arrives at hospital alive given that AED was not used	0.198	Beta	4218	17,127
Patient is discharged from hospital alive given that AED was used	0.443	Beta	108	136
Patient is discharged from hospital alive given that AED was not used	0.315	Beta	1327	2891
Acquisition cost for an AED unit	£840	Gamma	100	8
Cost of in-hospital post-cardiac-arrest care if patient is discharged alive	£42,419	Gamma	100	424
Cost of in-hospital post-cardiac-arrest care if patient dies before discharge	£15,604	Gamma	100	156
Cost of emergency care, patient dead on arrival	£718	Gamma	100	7
Cost of pre-hospital EMS care	£367	Gamma	100	4
Cost of post-discharge care (CPC 1 or 2)	£3626	Gamma	100	36
Cost of post-discharge care (CPC 3 or 4)	£47,029	Gamma	100	470
Utility of patient discharged from hospital	0.538	Beta	46	39
Utility of patient classified as CPC1, first year after discharge	0.670	Beta	32	16
Utility of patient classified as CPC2, first year after discharge	0.390	Beta	61	95
Utility of patient classified as CPC3, first year after discharge	0.220	Beta	78	276
Utility of patient classified as CPC1, subsequent years	0.770	Beta	22	7
Utility of patient classified as CPC2, subsequent years	0.490	Beta	51	53
Utility of patient classified as CPC3, subsequent years	0.320	Beta	68	144
Probability patient is classified as CPC1 at hospital discharge	0.667	Beta	22	11
Probability patient is classified as CPC2 at hospital discharge	0.121	Beta	4	29

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TABLE 39 Parameters and distributions used in PSA (*continued*)

	Base-case point estimate	Distribution family	Parameter a	Parameter b
Probability patient is classified as CPC3 at hospital discharge	0.152	Beta	5	28
Probability patient is classified as CPC4 at hospital discharge	0.061	Beta	2	31
Probability patient in state CPC1 dies during the first year after discharge	0.086	Beta	52	554
Probability patient in state CPC2 dies during the first year after discharge	0.233	Beta	53	174
Probability patient in state CPC3 dies during the first year after discharge	0.361	Beta	35	62
Probability patient in state CPC4 dies during subsequent years	0.720	Beta	36	14
Probability patient in state CPC1 dies during subsequent years	0.051	Beta	28	526
Probability patient in state CPC2 dies during subsequent years	0.080	Beta	14	160
Probability patient in state CPC3 dies during subsequent years	0.081	Beta	5	57
Probability patient in state CPC4 dies during subsequent years	0.071	Beta	1	13

TABLE 40 Probabilities of public-access AED being available for different scenario analyses and numbers of additional public-access AEDs needed for each compared placement

Compared placements	Alternative scenario 1[a]		Alternative scenario 2[b]		Alternative scenario 3[c]	
	Probability available	No. of additional required	Probability available	No. of additional required	Probability available	No. of additional required
CP	0.388	0	0.021	0	0.254	0
Public houses, bars and inns	0.567	10,576	0.051	3538	0.396	11,755
Post office	0.494	4094	0.026	593	0.279	2060
Place of worship	0.643	14,718	0.040	2385	0.356	9826
Chemists and pharmacies	0.527	5937	0.031	1154	0.288	2946
Dental surgeries	0.485	4209	0.026	619	0.267	1001
Doctors' surgeries	0.486	4152	0.026	574	0.270	1152
Cash machines	0.67	15,190	0.087	6737	0.651	21,579
Banks and building societies	0.426	1995	0.026	621	0.260	451
Nursing and residential care homes	0.581	9834	0.085	5617	0.518	12,689
Halls and community centres	0.538	7642	0.042	2311	0.496	10,809
Gyms, sports halls and leisure centres	0.528	7326	0.032	1236	0.354	7201
Supermarket chains	0.463	3284	0.028	775	0.314	3780
State first, primary, and infant schools	0.571	8752	0.024	363	0.272	1805
State secondary schools	0.422	1791	0.022	69	0.257	319

a Alternative scenario 1: probability of coverage calculated by accounting for the existence of already installed AEDs; based on 24/7 availability of AED; for distance of 500 m between OHCA and AED.
b Alternative scenario 2: probability of coverage calculated by accounting for the existence of already installed AEDs; based on actual (i.e. not 24/7) availability of AED; for distance of 100 m between OHCA and AED.
c Alternative scenario 3: probability of coverage calculated by accounting for the existence of already installed AEDs; based on actual (i.e. not 24/7) availability of AED; for distance of 1000 m between OHCA and AED.

Appendix 3 Temporal variability of out-of-hospital cardiac arrest occurrence (numbers and proportions)

Hour of the day in which OHCAs occurred

TABLE 41 Number and proportion of OHCAs that occurred by hour of the day and 6-hour call period

Hour of the day	Number	Percentage
00.00–00.59	3781	2.6
01.00–01.59	3299	2.2
02.00–02.59	3032	2.1
03.00–03.59	2882	2.0
04.00–04.59	3022	2.0
05.00–05.59	3487	2.4
06.00–06.59	4782	3.2
07.00–07.59	6676	4.5
08.00–08.59	8046	5.5
09.00–09.59	8806	6.0
10.00–10.59	8255	5.6
11.00–11.59	7379	5.0
12.00–12.59	7106	4.8
13.00–13.59	6621	4.5
14.00–14.59	6217	4.2
15.00–15.59	6097	4.1
16.00–16.59	6409	4.3
17.00–17.59	6593	4.5
18.00–18.59	6419	4.4
19.00–19.59	6259	4.2
20.00–20.59	5991	4.1
21.00–21.59	5792	3.9
22.00–22.59	5591	3.8
23.00–23.59	4599	3.1
Unknown	10,137	6.9
Total	147,278	100.00

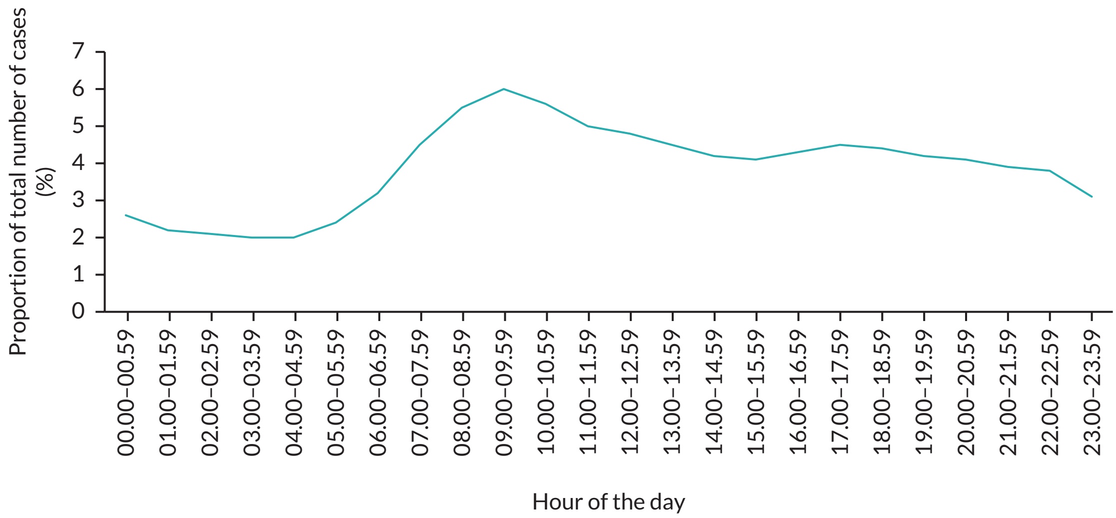

FIGURE 20 Hour of the day in which OHCAs occurred.

Day of the week when OHCAs occurred

TABLE 42 Number and proportion of OHCAs that occurred by day of week

Day of the week	Number	Percentage
Sunday	21,811	14.8
Monday	21,569	14.6
Tuesday	20,654	14.0
Wednesday	20,496	13.9
Thursday	20,530	13.9
Friday	20,803	14.1
Saturday	21,149	14.4
Unknown	266	0.2
Total	147,278	100.00

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Hour of the day and day of the week when OHCAs occurred

TABLE 43 Proportion of OHCAs (*n* = 147,278) that occurred on different days of week and times of day

	Day of week							
Time of day	**Sunday**	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Total**
Number of OHCAs								
00.00–05.59	3227	2853	2709	2585	2616	2618	2895	19,503
06.00–11.59	6230	6732	6283	6096	6208	6267	6128	43,944
12.00–17.59	5877	5653	5402	5569	5426	5602	5514	39,043
18.00–23.59	5023	4915	4920	4890	4918	4860	5125	34,651
Total	21,811	21,569	20,654	20,496	20,530	20,803	21,149	147,278
Proportion (%) of all cases								
00.00–05.59	2.2	1.9	1.8	1.8	1.8	1.8	2.0	13.2
06.00–11.59	4.2	4.6	4.3	4.1	4.2	4.3	4.2	29.8
12.00–17.59	4.0	3.8	3.7	3.8	3.7	3.8	3.7	26.5
18.00–23.59	3.4	3.3	3.3	3.3	3.3	3.3	3.5	23.5
All times	14.8	14.6	14.0	13.9	13.9	14.1	14.4	

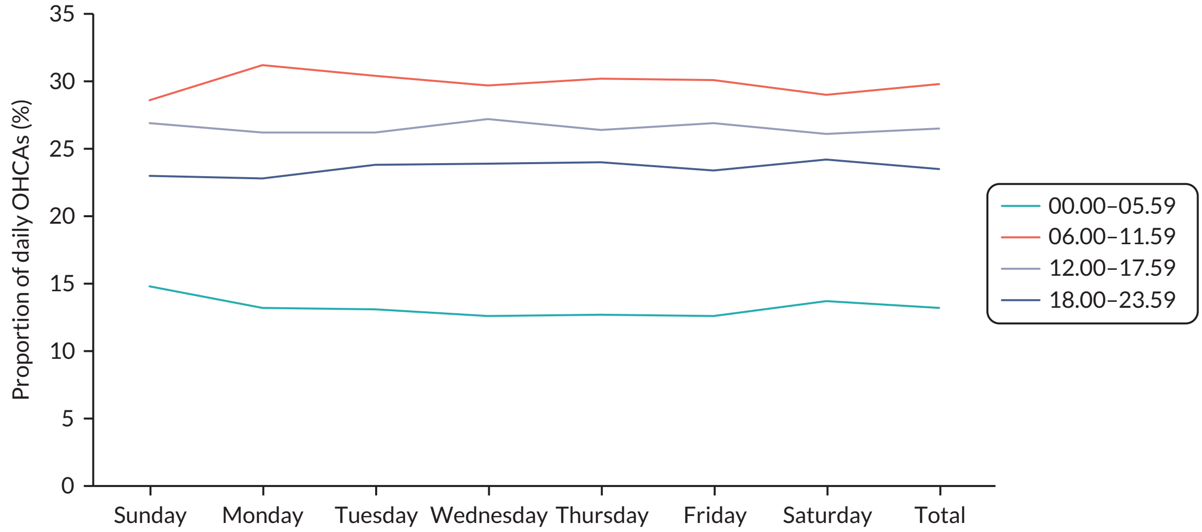

FIGURE 21 Hour of the day and day of the week in which OHCAs occurred.

Month of year when OHCAs occurred

TABLE 44 Number and proportion of OHCAs that occurred by month of year

Month	Number	Percentage
January	13,875	9.4
February	11,787	8.0
March	12,118	8.2
April	12,392	8.4
May	11,831	8.0
June	11,495	7.8
July	11,524	7.8
August	11,531	7.8
September	11,251	7.6
October	12,453	8.5
November	12,422	8.4
December	14,333	9.7
Unknown	266	0.2
Total	147,278	100.00

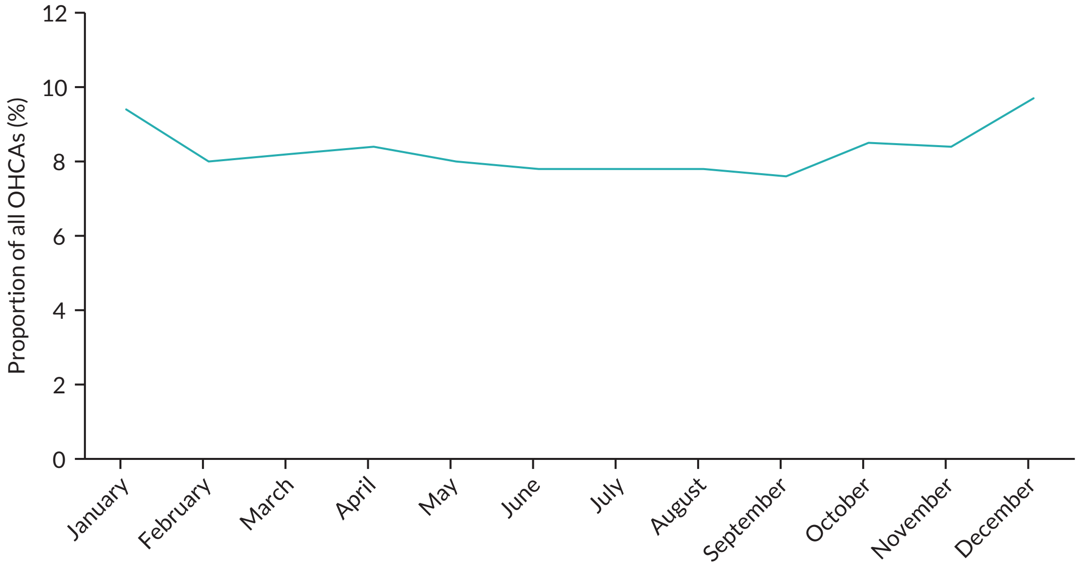

FIGURE 22 Month of the year in which OHCAs occurred.

Appendix 4 Logistic regression results for out-of-hospital cardiac arrest

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TABLE 45 Odds ratio for bivariate logistic regression analysis, dependent variable being whether an OHCA had occurred within a LSOA or not

	OR	SE	Z	*p*	95% CI
Population density (N/hectare)					
Residential	1.007	0.001	10.71	0	1.006 to 1.009
Workday	1.008	0.001	10.73	0	1.007 to 1.010
Workplace	1.007	0.001	5.44	0	1.004 to 1.009
Proportion of population aged (years)					
< 65	0.977	0.003	−7.207	0	0.971 to 0.983
≥ 65	1.024	0.003	7.24	0	1.017 to 1.030
Proportion of population in specific ethnic group					
White	0.986	0.001	−8.90	0	0.984 to 0.990
Mixed	1.058	0.013	4.41	0	1.032 to 1.084
Non-white[a]	1.016	0.002	9.23	0	1.012 to 1.019
Proportion of population in specific occupations					
Management and professional	0.974	0.002	−14.59	0	0.971 to 0.978
Intermediate	0.928	0.004	−16.92	0	0.920 to 0.936
Routine and manual	1.034	0.002	14.26	0	1.029 to 1.039
Unemployed and other	1.026	0.003	7.95	0	1.019 to 1.032
Proportion educated to A-level and above	0.986	0.002	−8.85	0	0.983 to 0.989
Long-term health limits day-to-day activity a lot	1.21	0.01	23.45	0	1.191 to 1.229
IMD					
Rank	0.999	< 0.001	−17.89	0	0.999 to 0.999
Decile	0.864	0.007	−17.89	0	0.850 to 0.878

OR, odds ratio; SE, standard error.
a Asian, black, other.

TABLE 46 Results of stepwise logistic regression analysis for variables that were significant in *Table 45*

	OR	SE	Z	p	95% CI
Population density					
Workday	1.018	0.002	11.01	0	1.014 to 1.021
Workplace	0.986	0.002	−7.26	0	0.982 to 0.990
Proportion of population aged ≥ 65 years	1.067	0.004	18.11	0	1.059 to 1.074
Proportion of population from non-white ethnic groups	1.013	0.002	6.13	0	1.009 to 1.017
Proportion of population in specific occupations					
Management and professional	0.976	0.003	−6.99	0	0.970 to 0.983
Intermediate	0.961	0.007	−5.80	0	0.948 to 0.974
Unemployed and other	0.969	0.005	−6.67	0	0.961 to 0.978
IMD decile	0.947	0.012	−4.32	0	0.923 to 0.971
Final model after checking for collinearity and correlation					
Working population density	1.006	0.001	6.14	0	1.004 to 1.008
Proportion of population aged ≥ 65 years	1.077	0.004	18.01	0	1.068 to 1.086
Proportion of population from mixed ethnic groups	0.907	0.018	−4.92	0	0.873 to 0.943
Proportion of population from non-white ethnic groups	1.024	0.003	8.92	0	1.019 to 1.030
Proportion of population in specific occupations					
Intermediate	0.906	0.006	−15.88	0	0.895 to 0.917
Unemployed and non-categorised	0.958	0.004	−10.74	0	0.951 to 0.966
IMD decile	0.861	0.008	−16.03	0	0.845 to 0.877

OR, odds ratio; SE, standard error.

Appendix 5 Neighbourhood characteristics of locations of automated external defibrillators registered on The Circuit

TABLE 47 Neighbourhood characteristics of LSOAs in which AEDs registered on The Circuit are located compared to LSOAs where an AED was not registered as of June 2022 (percentage unless stated)

	LSOAs where an AED is registered (*n* = 15,326)		LSOAs where an AED is not registered (*n* = 17,518)	
	Mean	**SD**	**Mean**	**SD**
Population density (N/hectare)				
Residential	26.9	30.1	56.4	46.3
Workday	31.4	60.4	44.9	44.7
Workplace	17.4	53.8	15	28.5
Proportion of population aged > 65 years	18.3	7.4	15.2	6.8
Proportion of population in different ethnic groups				
White	91	13.8	82	21.3
Mixed	1.7	1.5	2.6	2.1
Non-white	7.3	12.8	15.4	20
Proportion of population in different socioeconomic groups				
Management and professional	32.7	11.5	30	12.7
Intermediate	30.2	5.5	28.7	5.5
Routine/manual	24.8	9.8	25.9	10.4
Unemployed/not classified	12.4	8.9	15.3	9.3
Proportion educated to A-level and above	45.1	12.6	44.5	14.5
Long-term health limits day-to-day activity a lot	8.4	3.5	8.4	3.5
IMD				
Rank	17,658	9045	15,341	9720
Decile	5.9	2.7	5.1	2.9

Appendix 6 Neighbourhood characteristics of automated external defibrillator locations in each ambulance service region

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TABLE 48 Neighbourhood characteristics (% unless stated) of AED locations within EEAS, EMAS and IOWAS compared with characteristics of region as a whole (mean and SD)

	EEAS		EMAS		IOWAS	
	AED locations (*n* = 2391)	Regional average (*n* = 3614)	AED locations (*n* = 5883)	Regional average (*n* = 2774)	AED locations (*n* = 159)	Regional average (*n* = 89)
Population density (N/hectare)						
Residential	11.9 (18.3)	29.1 (26.5)	19.5 (24.9)	30.2 (31.5)	15.5 (18.8)	23.3 (23.7)
Workday	14.6 (29.9)	25.0 (25.5)	27.7 (45.4)	27.0 (34.0)	18.4 (29.7)	21.8 (25.8)
Workplace	8.4 (24.5)	10.1 (17.3)	17.1 (37.2)	10.6 (22.3)	9.8 (23.2)	8.9 (17.1)
Age group						
< 65	79.5 (7.1)	82.2 (7.4)	81.5 (7.0)	82.7 (6.8)	72.6 (8.5)	75.8 (8.2)
≥ 65	20.5 (7.1)	17.8 (7.4)	18.5 (7.0)	17.3 (6.8)	27.4 (8.5)	24.2 (8.2)
Ethnic group						
White	95.5 (6.5)	91.2 (10.8)	92.1 (13.7)	89.7 (16.7)	97.4 (1.7)	97.4 (1.6)
Mixed	1.3 (1.0)	1.9 (1.2)	1.6 (1.6)	1.9 (1.9)	1.2 (0.7)	1.2 (0.8)
Non-white	3.2 (5.8)	6.9 (10.0)	6.3 (12.7)	8.5 (15.7)	1.5 (1.2)	1.4 (1.1)
SEC						
Management/professional	34.4 (9.2)	32.5 (10.6)	29.8 (10.8)	28.5 (10.8)	30.6 (6.8)	28.2 (6.5)
Intermediate	32.7 (4.2)	31.5 (4.8)	29.4 (5.5)	29.3 (5.2)	34.3 (3.0)	33.1 (3.4)
Routine/manual	23.5 (7.9)	24.9 (8.9)	27.8 (10.5)	29.2 (10.0)	26.1 (6.1)	28.7 (6.2)
Unemployed/not classified	9.4 (5.6)	11.1 (6.4)	13.0 (10.6)	13.0 (9.7)	9.0 (2.5)	10.0 (2.7)
Living alone	35.1 (7.6)	38.3 (8.2)	39.3 (11.1)	39.2 (10.2)	38.3 (6.9)	39.7 (6.6)
Educated to A-level and above	43.6 (9.5)	42.5 (11.3)	42.8 (11.9)	41.1 (11.4)	41.1 (6.1)	39.2 (6.0)
Long-term health limits day-to-day activity a lot	7.7 (2.9)	7.5 (3.0)	8.9 (3.6)	8.8 (3.4)	10.5 (2.2)	10.4 (2.3)

continued

TABLE 48 Neighbourhood characteristics (% unless stated) of AED locations within EEAS, EMAS and IOWAS compared with characteristics of region as a whole (mean and SD) (*continued*)

	EEAS		EMAS		IOWAS	
	AED locations	Regional average	AED locations	Regional average	AED locations	Regional average
	(*n* = 2391)	(*n* = 3614)	(*n* = 5883)	(*n* = 2774)	(*n* = 159)	(*n* = 89)
Household deprivation dimensions						
None	46.6 (9.6)	45.0 (11.1)	43.3 (11.5)	42.9 (11.7)	40.6 (6.2)	39.2 (6.8)
1	32.9 (3.4)	32.9 (3.6)	32.6 (3.5)	32.4 (3.4)	35.8 (3.0)	34.9 (3.0)
2	16.9 (5.5)	17.8 (6.4)	19.2 (6.7)	19.6 (6.9)	19.1 (4.2)	20.4 (4.4)
3	3.3 (2.4)	3.9 (2.8)	4.6 (3.4)	4.7 (3.5)	4.0 (2.2)	4.9 (2.5)
4	0.3 (0.4)	0.4 (0.5)	0.4 (0.6)	0.4 (0.5)	0.5 (0.5)	0.5 (0.5)
IMD rank	18,857 (7483)	18,866 (8641)	16,953 (8923)	17,182 (9449)	15,094 (6389)	13,356 (6363)
IMD decile	6.2 (2.3)	6.2 (2.6)	5.7 (2.7)	5.7 (2.9)	5.2 (2.0)	4.6 (2.0)

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TABLE 49 Neighbourhood characteristics (% unless stated) of AED locations within LAS, NEAS and NWAS compared with characteristics of region as a whole (mean and SD)

	LAS		NEAS		NWAS	
	AED locations (*n* = 4710)	Regional average (*n* = 4835)	AED locations (*n* = 535)	Regional average (*n* = 1657)	AED locations (*n* = 3909)	Regional average (*n* = 4497)
Population density (N/hectare)						
Residential	76.4 (56.6)	95.9 (61.2)	13.60 (19.3)	34.8 (27.2)	29.1 (24.8)	38.3 (28.8)
Workday	213.4 (317.5)	89.8 (100.8)	17.1 (33.3)	30.2 (27.6)	51.4 (87.2)	34.7 (34.6)
Workplace	175.5 (320.4)	41.0 (91.4)	9.4 (27.3)	10.6 (18.9)	35.7 (84.4)	13.5 (27.0)
Age group (%) (years)						
< 65	89.1 (5.2)	88.7 (4.9)	79.5 (5.9)	82.4 (6.2)	83.5 (7.2)	83.1 (6.7)
≥ 65	10.9 (5.2)	11.3 (4.9)	20.5 (5.9)	17.6 (6.2)	16.5 (7.2)	16.9 (6.7)
Ethnic group (%)						
White	63.8 (18.7)	60.7 (20.4)	97.1 (6.1)	95.6 (7.3)	89.2 (15.9)	91.0 (14.9)
Mixed	4.8 (1.8)	4.9 (1.9)	0.7 (0.5)	0.8 (0.6)	1.7 (1.4)	1.5 (1.3)
Non-white	31.4 (18.1)	34.4 (19.9)	2.3 (5.7)	3.6 (6.9)	9.1 (15.0)	7.5 (14.1)
SEC						
Management/professional	40.8 (15.4)	36.1 (14.1)	30.6 (10.9)	25.8 (11.4)	29.7 (12.8)	28.4 (12.1)
Intermediate	24.5 (6.6)	26.5 (5.8)	31.0 (6.1)	28.1 (5.4)	28.4 (5.9)	29.3 (5.2)
Routine/manual	15.5 (7.3)	17.9 (7.0)	26.7 (9.8)	31.3 (10.8)	26.8 (10.9)	27.9 (10.2)
Unemployed/not classified	19.2 (9.2)	19.4 (8.4)	11.7 (10.1)	14.8 (9.6)	15.0 (11.9)	14.4 (9.5)
Living alone	53.3 (9.9)	51.5 (9.7)	38.5 (9.8)	42.8 (10.5)	45.0 (11.8)	43.9 (11.0)
Educated to A-level and above	62.7 (15.1)	57.6 (14.0)	43.6 (11.4)	38.5 (13.0)	44.3 (14.4)	41.2 (12.6)
Long-term health limits day-to-day activity a lot	6.3 (2.8)	6.8 (2.3)	10.0 (3.4)	11.1 (3.9)	9.7 (4.0)	10.4 (3.9)

continued

TABLE 49 Neighbourhood characteristics (% unless stated) of AED locations within LAS, NEAS and NWAS compared with characteristics of region as a whole (mean and SD) (*continued*)

	LAS		NEAS		NWAS	
	AED locations (*n* = 4710)	Regional average (*n* = 4835)	AED locations (*n* = 535)	Regional average (*n* = 1657)	AED locations (*n* = 3909)	Regional average (*n* = 4497)
Household deprivation dimensions						
None	40.8 (12.5)	39.4 (12.5)	43.9 (10.0)	39.9 (12.1)	41.3 (12.2)	40.8 (12.5)
1	35.1 (5.0)	34.2 (4.4)	32.2 (3.2)	31.6 (3.1)	32.2 (4.5)	31.7 (3.4)
2	17.7 (6.7)	19.3 (6.6)	19.0 (6.4)	21.9 (7.5)	19.9 (7.2)	20.7 (7.2)
3	5.6 (3.6)	6.2 (3.6)	4.6 (3.3)	6.2 (4.1)	6.0 (4.4)	6.3 (4.6)
4	0.8 (0.7)	0.9 (0.8)	0.3 (0.4)	0.4 (0.4)	0.6 (0.7)	0.6 (0.7)
IMD rank	15,938 (8004)	15,198 (8093)	15,229 (7913)	12,946 (9701)	13,787 (9624)	13,497 (10,009)
IMD decile	5.3 (2.5)	5.1 (2.5)	5.1 (2.4)	4.5 (2.9)	4.7 (2.9)	4.6 (3.0)

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TABLE 50 Neighbourhood characteristics (% unless stated) of AED locations within SCAS, SECAmb and SWAST compared with characteristics of region as a whole (mean and SD)

	SCAS		SECAmb		SWAST	
	AED locations (*n* = 2506)	Regional average (*n* = 2609)	AED locations (*n* = 3306)	Regional average (*n* = 2775)	AED locations (*n* = 3102)	Regional average (*n* = 3281)
Population density (N/hectare)						
Residential	18.1 (23.0)	34.5 (31.5)	23.8 (27.9)	33.8 (33.3)	10.1 (16.6)	29.4 (28.2)
Workday	25.8 (42.7)	29.9 (30.7)	32.0 (46.9)	29.8 (32.9)	12.4 (26.6)	26.8 (31.7)
Workplace	16.7 (36.7)	12.6 (21.0)	20.0 (38.9)	12.8 (22.8)	7.1 (21.1)	11.8 (23.4)
Age group (%)						
< 65 years	81.8 (7.2)	84.0 (7.2)	80.2 (7.7)	81.5 (7.6)	77.2 (6.5)	80.2 (8.0)
≥ 65 years	18.2 (7.2)	16.0 (7.2)	19.8 (7.7)	18.5 (7.6)	22.8 (6.6)	19.8 (8.0)
Ethnic group (%)						
White	92.4 (8.9)	88.7 (12.7)	93.3 (6.5)	92.8 (6.3)	97.6 (3.1)	95.6 (6.4)
Mixed	1.7 (1.1)	2.1 (1.3)	1.7 (1.0)	1.8 (1.0)	0.9 (0.6)	1.3 (1.1)
Non-white	5.8 (8.1)	9.2 (11.9)	5.0 (5.8)	5.4 (5.8)	1.5 (2.6)	3.1 (5.5)
SEC						
Management/professional	41.2 (9.9)	37.1 (11.2)	37.0 (10.0)	35.4 (10.9)	34.7 (7.9)	31.8 (9.6)
Intermediate	29.3 (5.1)	29.5 (4.9)	31.5 (4.8)	31.6 (4.6)	33.9 (5.0)	31.5 (5.2)
Routine/manual	18.6 (7.2)	21.8 (8.6)	20.3 (7.6)	21.7 (8.4)	22.3 (6.9)	25.8 (8.8)
Unemployed/not classified	10.8 (9.9)	11.7 (8.6)	11.2 (7.4)	11.2 (6.5)	9.1 (5.9)	10.9 (7.4)
Living alone	36.3 (9.3)		39.3 (9.3)	39.1 (8.8)	35.2 (7.4)	38.8 (9.4)
Educated to A-level and above	52.5 (10.4)	49.1 (11.6)	48.1 (10.8)	46.0 (11.6)	47.0 (8.4)	44.5 (11.4)
Long-term health limits day-to-day activity a lot	6.3 (2.6)	6.3 (2.6)	7.6 (3.2)	7.4 (3.1)	8.1 (2.7)	8.3 (3.1)

continued

TABLE 50 Neighbourhood characteristics (% unless stated) of AED locations within SCAS, SECAmb and SWAST compared with characteristics of region as a whole (mean and SD) (*continued*)

	SCAS		SECAmb		SWAST	
	AED locations (*n* = 2506)	Regional average (*n* = 2609)	AED locations (*n* = 3306)	Regional average (*n* = 2775)	AED locations (*n* = 3102)	Regional average (*n* = 3281)
Household deprivation dimensions						
None	52.6 (9.9)	49.9 (11.4)	47.2 (10.4)	46.7 (11.0)	47.0 (8.3)	45.0 (10.1)
1	30.8 (3.7)	31.5 (3.9)	32.6 (3.5)	32.6 (3.6)	33.4 (3.1)	33.1 (3.4)
2	13.6 (5.4)	14.9 (6.1)	16.2 (5.9)	16.6 (6.2)	16.2 (4.8)	17.5 (5.9)
3	2.7 (2.3)	3.3 (2.7)	3.6 (2.6)	3.8 (2.9)	3.2 (1.9)	4.0 (2.8)
4	0.3 (0.4)	0.3 (0.4)	0.4 (0.5)	0.4 (0.5)	0.3 (0.4)	0.4 (0.5)
IMD rank	23,269 (7286)	21,748 (8712)	19,735 (8154)	19,689 (8759)	18,524 (6786)	18,130 (8448)
IMD decile	7.6 (2.2)	7.1 (2.6)	6.5 (2.5)	6.5 (2.7)	6.1 (2.1)	6.0 (2.6)

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TABLE 51 Neighbourhood characteristics (% unless stated) of AED locations within WMAS and YAS compared with characteristics of region as a whole (mean and SD)

	WMAS		YAS	
	AED locations (*n* = 4457)	Regional average (*n* = 3488)	AED locations (*n* = 1435)	Regional average (*n* = 3317)
Population density (N/hectare)				
Residential	20.0 (21.1)	36.4 (27.4)	13.1 (20.3)	33.3 (30.0)
Workday	32.9 (67.7)	32.4 (30.9)	18.0 (44.0)	30.6 (34.6)
Workplace	21.8 (64.6)	11.7 (22.5)	11.1 (38.8)	11.9 (24.9)
Age group (years)				
< 65	80.9 (7.1)	82.8 (6.7)	80.1 (6.2)	83.1 (6.7)
≥ 65	19.1 (7.1)	17.2 (6.7)	19.9 (6.2)	16.9 (6.7)
Ethnic group				
White	89.2 (16.4)	83.7 (21.2)	95.6 (9.3)	89.6 (17.3)
Mixed	1.8 (1.7)	2.3 (1.9)	0.9 (0.8)	1.6 (1.4)
Non-white	9.1 (15.2)	14.0 (20.1)	3.5 (8.7)	8.8 (16.5)
SEC				
Management/professional	31.0 (10.9)	27.5 (11.6)	34.7 (9.6)	27.4 (12.0)
Intermediate	29.6 (6.4)	28.5 (5.3)	32.3 (5.7)	28.8 (5.8)
Routine/manual	25.3 (9.8)	28.7 (9.9)	22.8 (8.4)	29.2 (10.7)
Unemployed/not classified	14.1 (12.0)	15.2 (10.1)	10.2 (8.4)	14.6 (11.1)
Living alone	40.4 (11.0)	41.8 (10.1)	35.3 (9.1)	40.9 (10.7)
Educated to A-level and above	44.3 (11.6)	40.4 (11.6)	46.7 (10.3)	40.1 (13.4)
Long-term health limits day-to-day activity a lot	8.9 (3.2)	9.1 (3.0)	7.9 (3.1)	9.2 (3.6)

continued

TABLE 51 Neighbourhood characteristics (% unless stated) of AED locations within WMAS and YAS compared with characteristics of region as a whole (mean and SD) (*continued*)

	WMAS		YAS	
	AED locations (*n* = 4457)	Regional average (*n* = 3488)	AED locations (*n* = 1435)	Regional average (*n* = 3317)
Household deprivation dimensions				
None	42.9 (11.1)	39.9 (12.1)	48.0 (10.2)	40.9 (12.9)
1	32.7 (3.8)	32.5 (3.2)	32.1 (3.8)	32.4 (3.7)
2	19.3 (6.7)	21.3 (7.3)	16.2 (6.0)	20.5 (7.6)
3	4.7 (3.4)	5.7 (3.9)	3.4 (2.7)	5.7 (4.0)
4	0.4 (0.5)	0.5 (0.6)	0.3 (0.5)	0.5 (0.6)
IMD rank	15,991 (8463)	14,400 (9513)	19,216 (7827)	14,357 (9921)
IMD decile	5.4 (2.6)	4.9 (2.9)	6.3 (2.4)	4.9 (3.0)

Appendix 7 Logistic regression results for automated external defibrillator location

TABLE 52 Bivariate logistic regression results where dependent variable was whether a LSOA had an AED located within it or not

	OR	SE	*Z*	*p*	95% CI
Population density					
Residential	0.989	0.0003	−34.51	0	0.988 to 0.989
Workday	0.999	0.0002	−2.90	0.008	0.9989 to 0.9998
Workplace	1.007	0.0005	15.06	0	1.006 to 1.008
Proportion of population aged (years)					
< 65	0.96	0.002	−26.11	0	0.957 to 0.963
≥ 65	1.042	0.002	26.12	0	1.039 to 1.045
Proportion of population in specific ethnic group					
White	1.008	0.0006	12.67	0	1.007 to 1.009
Mixed	0.932	0.006	−11.65	0	0.921 to 0.943
Non-white[a]	0.992	0.001	−12.29	0	0.991 to 0.993
Proportion of population in specific occupations					
Management and professional	1.028	0.001	29.62	0	1.026 to 1.030
Intermediate	1.027	0.002	12.90	0	1.023 to 1.031
Routine and manual	0.97	0.001	−27.13	0	0.968 to 0.972
Unemployed and non-categorised	0.977	0.001	−17.08	0	0.975 to 0.980
Educated to A-level and above	1.02	0.001	23.66	0	1.018 to 1.021
Long-term health limits day-to-day activity a lot	0.963	0.003	−11.68	0	0.957 to 0.969
IMD					
Rank	1	< 0.0001	20.98	0	1.000 to 1.000
Decile	1.085	0.004	20.79	0	1.077 to 1.093

OR, odds ratio; SE, standard error.
a Asian, black, other.

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TABLE 53 Stepwise logistic regression results where dependent variable was whether a LSOA had an AED located within it or not

Stepwise results	OR	SE	*Z*	*p*	95% CI
Population density					
Residential	0.974	0.002	−14.96	0	0.970 to 0.977
Workday	1.017	0.003	5.00	0	1.010 to 1.024
Workplace	1.007	0.003	1.97	0	1.001 to 1.013
Proportion of population aged ≥ 65 years	1.023	0.002	10.28	0	1.018 to 1.027
Proportion of population from white ethnic group	0.993	0.001	−6.64	0	0.991 to 0.995
Proportion of population in specific occupations					
Management and professional	1.048	0.002	22.69	0	1.044 to 1.053
Intermediate	1.034	0.004	8.59	0	1.026 to 1.042
Unemployed and non-categorised	1.016	0.003	5.12	0	1.010 to 1.022
IMD decile	0.909	0.007	−12.43	0	0.895 to 0.922
Final model after checking for collinearity and correlation					
Population density					
Residential	0.983	0.0005	37.38	0	0.982 to 0.983
Workplace	1.023	0.001	27.8	0	1.021 to 1.025
Proportion of population aged ≥ 65 years	1.056	0.003	19.41	0	1.050 to 1.061
Proportion of population from mixed ethnic group	1.03	0.009	3.19	0	1.011 to 1.048
Proportion of population in specific occupations					
Management and professional	1.016	0.002	7.10	0	1.012 to 1.020
Routine and manual	0.98	0.003	−7.29	0	0.975 to 0.985
Long-term health limits day-to-day activity a lot	0.913	0.006	−13.18	0	0.901 to 0.925
IMD decile	0.858	0.008	−16.79	0	0.843 to 0.873

OR, odds ratio; SE, standard error.

Appendix 8 Rural–urban distribution of out-of-hospital cardiac arrest and automated external defibrillator locations

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TABLE 54 Distribution of LSOA with/without an OHCA and AED by RUC

RUC	OHCAs		AEDs		Population	No. of LSOAs
	Yes	No	Yes	No		
Major conurbation (A1)	32	635	4153 (36.0)	7370	18,849,335	11,523
Minor conurbation (B1)	1054 (87.3)	154	359 (29.7)	849	1,911,163	1208
City and town (C1)	13,148 (91.0)	1308	5389 (37.3)	9067	23,045,827	14,456
City and town in a sparse setting (C2)	48 (81.4)	11	36 (61.0)	23	90,739	59
Town and fringe (D1)	2662 (90.6)	275	1930 (65.7)	1007	4,724,456	2937
Town and fringe in a sparse setting (D2)	113 (95.0)	6	94 (79.0)	25	190,528	119
Village (E1)	2007 (85.0)	354	2082 (88.2)	279	3,902,807	2361
Village in a sparse setting (E2)	108 (59.7)	13	172 (95.0)	9	297,594	181
Total	30,088	2756	14,215	18,629	53,012,449	32,844

Appendix 9 Out-of-hospital cardiac arrest coverage by POIs and ambulance service region

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Public houses, bars and inns

TABLE 55 Number of OHCAs covered by public houses, bars and inns

Service	Number (%) of OHCAs covered				Number of POIs that covered the OHCAs	
	Registered AEDs	By POI only (ignoring registered AEDs)	By POI if not covered by a registered AED	By a registered AED or a POI	By POI only (ignoring registered AEDs)	By POI if not covered by a registered AED
EEAS	1140 (21.9)	1568 (30.1)	936 (23.0)	2076 (39.9)	1009	605
EMAS	5534 (47.4)	3891 (33.4)	1265 (20.7)	6799 (58.3)	1595	653
IOWAS	114 (62.6)	78 (42.9)	8 (11.8)	122 (67.0)	40	8
LAS	16,737 (63.8)	14,418 (55.0)	3824 (40.3)	20,562 (78.2)	3131	1649
NEAS	1705 (15.0)	4256 (37.6)	3227 (33.5)	4933 (43.5)	1116	833
NWAS	6854 (31.2)	8974 (40.8)	5222 (34.5)	12,078 (54.9)	2961	1873
SCAS	2744 (34.8)	2682 (34.0)	1174 (22.8)	3919 (49.7)	1154	809
SECAmb	5573 (42.0)	4759 (35.9)	1789 (23.2)	7362 (55.5)	1827	564
SWAST	4982 (28.4)	6565 (37.4)	3566 (28.4)	8549 (48.7)	2549	1462
WMAS	9969 (44.4)	7643 (34.1)	2860 (22.9)	12,831 (57.2)	2203	968
YAS	1782 (18.7)	3589 (37.6)	2542 (32.8)	4329 (45.4)	1692	1152
Total	57,134 (38.8)	58,423 (39.6)	26,413 (29.3)	83,560 (56.7)	19,277	10,576

TABLE 56 Out-of-hospital cardiac arrest coverage by AEDs deployed in public houses, bars and inns

		By pubs only (ignoring registered AEDs)				By pubs if not covered by a registered AED				By a registered AED or a pub			
Service	Number of pubs	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency
EEAS	3628	1568	844	46.2	23.3	936	510	45.5	14.1	2076	1131	45.5	31.2
EMAS	3659	3891	2073	46.7	56.7	1265	684	45.9	18.7	6799	3654	46.3	99.9
IOWAS	140	78	40	48.7	28.6	8	4	50.0	2.9	122	72	41.0	51.4
LAS	5009	14,418	6692	53.6	133.5	3825	1711	55.3	34.1	20,562	9483	53.9	189.3
NEAS	1721	4256	2336	45.1	135.7	3228	1768	45.2	102.7	4933	2682	45.6	155.8
NWAS	5452	8974	5217	41.9	95.7	5224	3019	42.2	55.4	12,078	6953	42.4	127.5
SCAS	3135	2682	1563	41.7	49.9	1175	671	42.9	21.4	3919	2256	42.4	72.0
SECAmb	3143	4759	2576	45.9	82.0	1789	955	46.6	30.4	7362	3952	46.3	125.7
SWAST	4199	6565	4004	39.0	95.4	3567	2147	39.8	51.1	8549	5150	39.8	122.6
WMAS	3573	7643	4529	40.7	126.7	2862	1678	41.4	47.0	12,831	7494	41.6	209.7
YAS	4169	3589	2018	43.8	48.4	2547	1431	43.8	34.3	4329	2408	44.4	57.8
Total	37,828	58,423	31,892	45.4	84.3	26,426	14,578	44.8	38.5	83,560	45,235	45.9	119.6

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Post offices

TABLE 57 Number of OHCAs covered by post offices

Service	Number (%) of OHCAs covered				Number of POIs that covered the OHCAs	
	Registered AEDs	By POI only (ignoring registered AEDs)	By POI if not covered by a registered AED	By a registered AED or a POI	By POI only (ignoring registered AEDs)	By POI if not covered by a registered AED
EEAS	1140 (21.9)	1007 (19.4)	583 (14.4)	1723 (33.1)	520	315
EMAS	5534 (47.4)	2454 (21.0)	724 (11.8)	6258 (53.6)	697	314
IOWAS	114 (62.6)	58 (31.9)	7 (10.3)	121 (66.5)	19	6
LAS	16,737 (63.8)	8012 (30.5)	2146 (22.6)	18,883 (72.0)	665	553
NEAS	1705 (15.0)	2930 (25.9)	2207 (22.9)	3912 (34.5)	373	312
NWAS	6854 (31.2)	5553 (25.3)	3171 (21.0)	10,025 (45.6)	944	698
SCAS	2744 (34.8)	1411 (17.9)	541 (10.5)	3285 (41.7)	394	190
SECAmb	5573 (42.0)	2730 (20.6)	890 (11.6)	6463 (48.7)	611	306
SWAST	4982 (28.4)	3958 (22.6)	1930 (15.4)	6913 (39.4)	914	523
WMAS	9969 (44.4)	5075 (22.6)	1870 (15.0)	11,840 (52.8)	763	432
YAS	1782 (18.7)	2285 (24.0)	1523 (19.6)	3305 (34.6)	642	445
Total	57,134 (38.8)	35,473 (24.0)	15,592 (17.3)	72,728 (49.4)	6542	4094

TABLE 58 Out-of-hospital cardiac arrest coverage by AEDs deployed in post offices

		By post offices only (ignoring registered AEDs)				By post offices if not covered by a registered AED				By a registered AED or a post office			
Service	Number of post offices	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency
EEAS	1014	1007	318	68.4	31.4	583	171	70.7	16.9	1723	553	67.9	54.5
EMAS	868	2454	760	69.0	87.6	724	217	70.0	25.0	6258	1948	68.9	224.4
IOWAS	37	58	17	70.7	45.9	7	2	71.4	5.4	121	38	68.6	102.7
LAS	658	8012	2348	70.7	356.8	2146	582	72.9	88.4	18,883	5319	71.8	808.4
NEAS	378	2930	1004	65.7	265.6	2207	745	66.2	197.1	3912	1337	65.8	353.7
NWAS	1047	5553	2150	61.3	205.3	3171	1163	63.3	111.1	10,025	3737	62.7	356.9
SCAS	714	1411	584	58.6	81.8	541	220	59.3	30.8	3285	1262	61.6	176.8
SECAmb	676	2730	969	64.5	143.3	890	286	67.9	42.3	6463	2205	65.9	326.2
SWAST	1033	3958	1509	61.9	146.1	1931	705	63.5	68.2	6913	2565	62.9	248.3
WMAS	842	5075	1856	63.4	220.4	1871	644	65.6	76.5	11,840	4255	64.1	505.3
YAS	856	2285	777	66.0	90.8	1523	521	65.8	60.9	3305	1092	67.0	127.6
Total	8123	35,473	12,292	65.3	151.3	15,594	5256	66.3	64.7	72,728	24,311	66.6	299.3

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Places of worship

TABLE 59 Number of OHCAs covered by places of worship

Service	Number (%) of OHCAs covered				Number of POIs that covered the OHCAs	
	Registered AEDs	By POI only (ignoring registered AEDs)	By POI if not covered by a registered AED	By a registered AED or a POI	By POI only (ignoring registered AEDs)	By POI if not covered by a registered AED
EEAS	1140 (21.9)	2188 (42.1)	1468 (36.1)	2608 (50.1)	1384	939
EMAS	5534 (47.4)	5177 (44.4)	1802 (29.5)	7336 (62.9)	2195	937
IOWAS	114 (62.6)	97 (53.3)	17 (25.0)	131 (72.0)	57	13
LAS	16,737 (63.8)	17,785 (67.8)	5278 (55.6)	22,016 (83.9)	3435	2191
NEAS	1705 (15.0)	6053 (53.4)	4831 (50.2)	6536 (57.7)	1349	1115
NWAS	6854 (31.2)	11,904 (54.1)	7259 (48.0)	14,117 (64.2)	3645	2501
SCAS	2744 (34.8)	3071 (38.9)	1521 (29.6)	4267 (54.1)	1286	727
SECAmb	5573 (42.0)	5859 (44.2)	2330 (30.3)	7903 (59.6)	2011	1036
SWAST	4982 (28.4)	8292 (47.3)	4883 (38.9)	9869 (56.3)	3098	2006
WMAS	9969 (44.4)	10,747 (47.9)	4601 (36.9)	14,576 (64.9)	2881	1620
YAS	1782 (18.7)	4936 (51.7)	3640 (46.9)	5427 (56.9)	2175	1633
Total	57,134 (38.8)	76,109 (51.6)	37,630 (41.7)	94,786 (64.3)	23,516	14,718

TABLE 60 Out-of-hospital cardiac arrest coverage by AEDs deployed in places of worship

		By places of worship only (ignoring registered AEDs)				By places of worship if not covered by a registered AED				By a registered AED or a place of worship			
Service	Number of places of worship	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency
EEAS	5209	2188	911	58.4	17.5	1468	604	58.9	116.0	2608	1091	58.2	20.9
EMAS	4443	5177	2102	59.4	47.3	1802	759	57.9	170.8	7336	3028	58.7	68.2
IOWAS	161	97	39	59.8	24.2	17	4	76.5	2.5	131	53	59.5	32.9
LAS	3929	17,785	6302	64.6	160.4	5279	1735	67.1	44.2	22,016	7776	64.7	197.9
NEAS	1667	6053	2564	57.6	153.8	4831	2014	58.3	120.8	6536	2767	57.7	166.0
NWAS	5185	11,904	5518	53.6	106.4	7263	3310	54.4	63.8	14,117	6556	53.6	126.4
SCAS	3605	3071	1477	51.9	41.0	1523	725	52.4	20.1	4267	2065	51.6	57.3
SECAmb	3139	5859	2580	56.0	82.2	2330	1043	55.2	33.3	7903	3471	56.1	110.6
SWAST	5332	8292	4021	51.5	75.4	4887	2360	51.7	44.3	9869	4764	51.7	89.3
WMAS	4397	10,747	4984	53.6	113.4	4607	2047	55.6	46.6	14,576	6722	53.9	152.9
YAS	4198	4936	2148	56.5	51.2	3645	1601	56.1	38.1	5427	2346	56.8	55.9
Total	41,265	76,109	32,646	57.1	79.1	37,652	16,202	57.0	39.3	94,786	40,639	57.1	98.5

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Chemists and pharmacies

TABLE 61 Number of OHCAs covered by chemists and pharmacies

Service	Number (%) of OHCAs covered				Number of POIs that covered the OHCAs	
	Registered AEDs	By POI only (ignoring registered AEDs)	By POI if not registered AED	By a registered AEDs or a POI	By POI only (ignoring registered AEDs)	By POI if not registered AED
EEAS	1140 (21.9)	1130 (21.7)	740 (18.2)	1880 (36.1)	602	399
EMAS	5534 (47.4)	2644 (22.7)	477 (7.8)	6011 (51.5)	789	220
IOWAS	114 (62.6)	59 (32.4)	4 (5.9)	118 (64.8)	20	3
LAS	16,737 (63.8)	14,249 (54.3)	3544 (37.3)	20,283 (77.3)	1837	1275
NEAS	1705 (15.0)	3713 (27.9)	2889 (30.0)	4594 (40.5)	551	468
NWAS	6854 (31.2)	7859 (35.7)	4162 (27.5)	11,018 (50.1)	1626	1012
SCAS	2744 (34.8)	1872 (23.7)	734 (14.3)	3478 (44.1)	545	275
SECAmb	5573 (42.0)	3605 (27.2)	1033 (13.4)	6606 (49.8)	810	343
SWAST	4982 (28.4)	4387 (25.0)	2376 (18.9)	7359 (42.0)	955	641
WMAS	9969 (44.4)	6985 (31.1)	2194 (17.6)	12,165 (54.2)	1178	547
YAS	1782 (18.7)	3032 (31.8)	2254 (29.1)	4037 (42.3)	949	754
Total	57,134 (38.8)	49,535 (33.6)	20,407 (22.6)	77,549 (52.7)	9862	5937

TABLE 62 Out-of-hospital cardiac arrest coverage by AEDs deployed in chemists and pharmacies

Service	Number of chemists and pharmacies	By chemists and pharmacies only (ignoring registered AEDs)				By chemists and pharmacies if not registered AED				By a registered AED or a chemist or pharmacy			
		Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency
EEAS	1139	1130	398	64.8	34.9	740	262	64.6	23.0	1880	689	63.4	60.5
EMAS	986	2644	936	64.6	94.9	477	176	63.1	17.8	6011	2105	65.0	213.5
IOWAS	30	59	21	64.4	70.0	4	0	100.0	0.0	118	42	64.4	140.0
LAS	1922	14,249	4430	68.9	230.5	3546	1030	71.0	53.6	20,283	6181	69.5	321.6
NEAS	541	3713	1392	62.5	257.3	2889	1071	62.9	198.0	4594	1702	63.0	314.6
NWAS	1771	7859	3201	59.3	180.7	4164	1644	60.5	92.8	11,018	4409	60.0	249.0
SCAS	854	1872	797	57.4	93.3	734	300	59.1	35.1	3478	1437	58.7	168.3
SECAmb	865	3605	1383	61.6	160.0	1033	384	62.8	44.4	6606	2469	62.6	285.4
SWAST	941	4387	1872	57.3	198.9	2377	995	58.1	105.7	7359	3003	59.2	319.1
WMAS	1271	6985	2839	59.4	223.3	2196	833	62.1	65.5	12,165	4784	60.7	376.4
YAS	1221	3032	1104	63.6	90.4	2255	821	63.6	67.2	4037	1445	64.2	118.3
Total	11,541	49,535	18,373	62.9	159.2	20,415	7516	63.2	65.1	77,549	28,266	63.6	244.9

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Dental surgeries

TABLE 63 Number of OHCAs covered by dental surgeries

	Number (%) of OHCAs covered				Number of POIs that covered the OHCAs	
Service	**Registered AEDs**	**By POI only (ignoring registered AEDs)**	**By POI if not registered AED**	**By a registered AED or a POI**	**By POI only (ignoring registered AEDs)**	**By POI if not registered AED**
EEAS	1140 (21.9)	921 (17.7)	589 (14.5)	1729 (33.2)	482	313
EMAS	5534 (47.4)	1855 (15.9)	385 (6.3)	5919 (49.9)	554	174
IOWAS	114 (62.6)	40 (22.0)	0 (0.0)	114 (62.6)	15	
LAS	16,737 (63.8)	12,002 (45.7)	3018 (31.8)	19,756 (75.3)	1543	1056
NEAS	1705 (15.0)	2578 (22.8)	1871 (19.4)	3576 (31.6)	337	276
NWAS	6854 (31.2)	5349 (24.3)	2765 (18.3)	9620 (43.8)	1039	622
SCAS	2744 (34.8)	1531 (19.4)	540 (10.5)	3284 (41.6)	487	227
SECAmb	5573 (42.0)	2907 (21.9)	798 (10.4)	6371 (48.0)	728	299
SWAST	4982 (28.4)	3290 (18.8)	1671 (13.3)	6653 (37.9)	732	476
WMAS	9969 (44.4)	4561 (20.3)	1227 (9.8)	11,197 (49.9)	775	327
YAS	1782 (18.7)	2047 (21.5)	1426 (18.4)	3209 (33.6)	605	439
Total	57,134 (38.8)	37,081 (25.2)	14,290 (15.9)	71,428 (48.5)	7297	4209

TABLE 64 Out-of-hospital cardiac arrest coverage by AEDs deployed in dental surgeries

Service	Number of dental surgeries	By dental surgeries only (ignoring registered AEDs)				By dental surgeries if not registered AED				By a registered AED or a dental surgery			
		Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency
EEAS	930	921	259	71.9	27.8	589	158	73.2	17.0	1729	504	70.9	54.2
EMAS	651	1855	510	72.5	78.3	385	119	69.1	18.3	5919	1642	72.3	252.2
IOWAS	22	40	13	67.5	59.1			0.0	0.0	114	30	73.7	1356.4
LAS	1682	12,002	3096	74.2	184.1	3019	723	76.1	43.0	19,756	4995	74.7	297.0
NEAS	315	2578	839	67.5	266.3	1871	600	67.9	190.5	3576	1131	68.4	359.0
NWAS	1123	5349	1886	64.7	167.9	2766	939	66.1	83.6	9620	3234	66.4	288.0
SCAS	791	1531	556	63.7	70.3	540	184	65.9	23.3	3284	1106	66.3	139.8
SECAmb	831	2907	908	68.8	109.3	798	243	69.5	29.2	6371	1966	69.1	236.6
SWAST	735	3290	1181	64.1	160.1	1671	596	64.3	81.1	6653	2266	65.9	308.3
WMAS	837	4561	1553	66.0	185.5	1228	394	67.9	47.1	11,197	3617	67.7	432.1
YAS	760	2047	649	68.3	85.4	1427	448	68.6	58.9	3209	959	70.1	126.2
Total	8677	37,081	11,450	69.1	132.0	14,294	4404	69.2	50.8	71,428	21,450	70.0	247.2

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Doctors surgeries

TABLE 65 Number of OHCAs covered by doctors' surgeries

Service	Number (%) of OHCAs covered				Number of POIs that covered the OHCAs	
	Registered AEDs	By POI only (ignoring registered AEDs)	By POI if not registered AED	By a registered AED or a POI	By POI only (ignoring registered AEDs)	By POI if not registered AED
EEAS	1140 (21.9)	987 (19.0)	620 (15.3)	1760 (33.8)	519	342
EMAS	5534 (47.4)	2146 (18.4)	287 (4.7)	5821 (49.9)	629	135
IOWAS	114 (62.6)	38 (20.9)	3 (4.4)	117 (64.3)	12	2
LAS	16,737 (63.8)	11,472 (43.7)	2496 (26.3)	19,233 (73.3)	1261	893
NEAS	1705 (15.0)	2658 (23.5)	2022 (21.0)	3727 (32.9)	374	317
NWAS	6854 (31.2)	5361 (24.4)	2560 (16.9)	9414 (42.8)	1041	580
SCAS	2744 (34.8)	1373	558 (10.9)	3302 (41.9)	389	203
SECAmb	5573 (42.0)	2708	728 (9.5)	6301 (47.5)	589	247
SWAST	4982 (28.4)	3389	1902 (15.1)	6885 (39.3)	716	496
WMAS	9969 (44.4)	5567	1540 (12.3)	11,511 (51.3)	868	376
YAS	1782 (18.7)	2413	1775 (22.9)	3558 (37.3)	710	561
Total	57,134 (38.8)	38,112	14,491 (16.1)	71,629 (48.6)	7108	4152

TABLE 66 Out-of-hospital cardiac arrest coverage by AEDs deployed in doctors' surgeries

Service	Number of doctors' surgeries	By doctors' surgeries only (ignoring registered AEDs)				By doctors' surgeries if not registered AED				By a registered AED or a doctor's surgery			
		Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency
EEAS	908	987	323	67.3	35.6	620	206	66.8	22.7	1760	597	66.1	65.7
EMAS	765	2146	689	67.9	90.1	287	112	61.0	14.6	5821	1833	68.5	239.6
IOWAS	21	38	9	76.3	42.3	3	1	66.7	4.8	117	37	68.4	176.2
LAS	1361	11,472	3163	72.4	232.4	2496	642	74.3	47.2	19,233	5328	72.3	391.5
NEAS	378	2658	869	67.3	229.9	2022	649	67.9	171.7	3727	1219	67.3	322.5
NWAS	1228	5361	1979	63.1	161.2	2560	916	64.2	74.6	9414	3402	63.9	277.0
SCAS	630	1373	528	61.5	83.8	558	202	63.8	32.1	3302	1219	63.1	193.5
SECAmb	674	2708	919	66.1	136.4	728	229	68.5	34.0	6301	2118	66.4	314.2
SWAST	738	3389	1291	61.9	174.9	1903	707	62.8	95.8	6885	2525	63.3	342.1
WMAS	979	5567	2032	63.5	207.6	1542	528	65.8	53.9	11,511	4091	64.5	417.9
YAS	939	2413	768	68.2	81.8	1776	569	68.0	60.6	3558	1133	68.2	120.7
Total	8621	38,112	12,570	67.0	145.8	14,294	4761	66.7	55.2	71,629	23,502	67.2	272.6

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Cash machines

TABLE 67 Number of OHCAs covered by cash machines

Service	Number (%) of OHCAs covered				Number of POIs that covered the OHCAs	
	Registered AEDs	By a POI only (ignoring registered AEDs)	By a POI if not by a registered AED	By a registered AED or a POI	By a POI only (ignoring registered AEDs)	By a POI if not by a registered AED
EEAS	1140 (21.9)	2145 (41.2)	1517 (37.3)	2657 (51.1)	1263	891
EMAS	5534 (47.4)	5481 (47.0)	2096 (34.3)	7630 (65.4)	2000	932
IOWAS	114 (62.6)	100 (54.9)	19 (27.9)	133 (73.1)	47	16
LAS	16,737 (63.8)	19,276 (73.5)	5752 (60.6)	22,496 (85.7)	4653	2577
NEAS	1705 (15.0)	7012 (61.9)	5787 (60.1)	7492 (66.1)	1582	1359
NWAS	6854 (31.2)	12,902 (58.7)	7767 (51.3)	14,627 (66.5)	3856	2557
SCAS	2744 (34.8)	3290 (41.7)	1711 (33.3)	4457 (56.5)	1303	735
SECAmb	5573 (42.0)	5867 (44.2)	2446 (31.8)	8023 (60.5)	1987	1005
SWAST	4982 (28.4)	7379 (42.1)	4534 (36.1)	9522 (54.3)	2395	1623
WMAS	9969 (44.4)	12,820 (57.1)	5906 (47.3)	15,882 (70.8)	3311	1807
YAS	1782 (18.7)	5040 (52.8)	3926 (50.6)	5716 (59.9)	2135	1688
Total	57,134 (38.8)	81,312 (55.1)	41,461 (46.0)	98,635 (67.0)	24,532	15,190

TABLE 68 Out-of-hospital cardiac arrest coverage by AEDs deployed at cash machines

		By a cash machine only (ignoring registered AEDs)				By a cash machine if not by a registered AED				By a registered AED or a cash machine			
Service	Number of cash machine	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency
EEAS	3819	2145	2145	0.0	56.2	1517	1517	0.0	39.7	2657	2657	0.0	69.6
EMAS	3511	5481	5481	0.0	156.1	2096	2096	0.0	59.7	7630	7630	0.0	217.3
IOWAS	112	100	100	0.0	89.3	19	19	0.0	17.0	133	133	0.0	118.8
LAS	6764	19,276	19,276	0.0	285.0	5759	5759	0.0	85.1	22,496	22,496	0.0	339.2
NEAS	1887	7012	7012	0.0	371.6	5787	5787	0.0	306.7	7492	7492	0.0	397.0
NWAS	5464	12,902	12,902	0.0	236.1	7773	7773	0.0	142.2	1,4,627	14,627	0.0	267.7
SCAS	2945	3290	3290	0.0	111.7	1713	1713	0.0	58.2	4457	4457	0.0	151.3
SECAmb	2905	5867	5867	0.0	202.0	2450	2450	0.0	84.3	8023	8023	0.0	276.2
SWAST	3156	7379	7379	0.0	233.8	4540	4540	0.0	144.0	9522	9522	0.0	301.7
WMAS	4424	12,820	12,820	0.0	289.8	5913	5913	0.0	13.4	15,882	15,882	0.0	359.0
YAS	3903	5040	5040	0.0	129.1	3934	3934	0.0	100.8	5716	5716	0.0	146.5
Total	38,890	81,312	81,312	0.0	32.3	41,501	41,501	0.0	106.7	98,635	98,635	0.0	253.6

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Banks and building societies

TABLE 69 Number of OHCAs covered by banks and building societies

Service	Number (%) of OHCAs covered				Number of POIs that covered the OHCAs	
	Registered AEDs	By a POI only (ignoring registered AEDs)	By a POI if not by a registered AED	By a registered AED or a POI	By a POI only (ignoring registered AEDs)	By a POI if not by a registered AED
EEAS	1140 (21.9)	325 (6.2)	133 (3.3)	1273 (24.5)	229	101
EMAS	5534 (47.4)	922 (7.9)	114 (1.9)	5648 (48.4)	337	60
IOWAS	114 (62.6)	25 (13.7)	0 (0.0)	114 (62.6)	9	
LAS	16,737 (63.8)	6519 (24.8)	1304 (13.7)	18,043 (68.8)	1034	534
NEAS	1705 (15.0)	1301 (11.5)	783 (8.1)	2488 (22.0)	242	150
NWAS	6854 (31.2)	2638 (12.0)	1133 (7.5)	7987 (36.3)	701	313
SCAS	2744 (34.8)	728 (9.2)	181 (3.5)	2926 (37.1)	283	85
SECAmb	5573 (42.0)	1416 (10.7)	226 (2.9)	5799 (43.7)	434	88
SWAST	4982 (28.4)	2195 (12.5)	856 (6.8)	5838 (33.3)	594	297
WMAS	9969 (44.4)	2434 (10.8)	448 (3.6)	10,418 (46.4)	570	137
YAS	1782 (18.7)	1067 (11.2)	606 (7.8)	2389 (25.0)	409	230
Total	57,134 (38.8)	19,570 (12.6)	5784 (6.3)	62,923 (42.6)	4842	1995

TABLE 70 Out-of-hospital cardiac arrest coverage by AEDs deployed in banks and building societies

Service	Number of banks and building societies	By a bank or building society only (ignoring registered AEDs)				By a bank or building society if not by a registered AED				By a registered AED or a bank or building society			
		Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency
EEAS	824	325	97	70.2	11.8	133	40	69.9	4.9	1273	386	69.7	46.8
EMAS	687	922	238	74.2	34.6	114	33	71.1	4.8	5648	1556	72.5	226.5
IOWAS	18	25	7	72.0	38.9					114	30	73.7	166.7
LAS	1579	6519	1798	72.4	113.9	1306	328	74.9	20.8	18,043	4600	74.5	291.3
NEAS	325	1301	445	65.8	136.9	783	269	65.6	82.8	2488	800	67.8	246.2
NWAS	1064	2638	992	62.4	93.2	1133	403	64.4	37.9	7987	2698	66.2	253.6
SCAS	706	728	301	58.7	42.6	182	75	58.8	10.6	2926	997	65.9	141.2
SECAmb	651	1416	506	64.3	77.7	226	85	62.4	13.1	5799	1808	68.8	277.7
SWAST	767	2195	829	62.2	108.1	856	320	62.6	41.7	5838	1990	65.9	259.5
WMAS	832	2434	884	63.7	106.3	449	139	69.0	16.7	10,418	3362	67.7	404.1
YAS	773	1067	362	66.1	46.8	607	201	66.9	26.0	2389	712	70.2	92.1
Total	8226	19,570	6459	67.0	78.5	5789	1893	67.3	23.0	62,923	18,939	69.9	230.2

Nursing and residential care homes

TABLE 71 Number of OHCAs covered by nursing and residential care homes

Service	Number (%) of OHCAs covered				Number of POIs that covered the OHCAs	
	Registered AEDs	By a POI only (ignoring registered AEDs)	By a POI if not by a registered AED	By a registered AED or a POI	By a POI only (ignoring registered AEDs)	By a POI if not by a registered AED
EEAS	1140 (21.9)	1772 (34.1)	1303 (32.1)	2443 (47.0)	984	752
EMAS	5534 (47.4)	3911 (33.5)	1568 (25.6)	7108 (60.9)	1316	709
IOWAS	114 (62.6)	83 (45.6)	14 (7.7)	128 (70.3)	50	12
LAS	16,737 (63.8)	11,590 (44.2)	3880 (40.8)	20,617 (78.6)	1708	1297
NEAS	1705 (15.0)	4439 (39.2)	3643 (37.8)	5348 (47.2)	808	723
NWAS	6854 (31.2)	8023 (36.5)	5064 (33.5)	11,923 (54.2)	1895	1451
SCAS	2744 (34.8)	2144 (27.2)	1199 (23.3)	3943 (50.0)	804	554
SECAmb	5573 (42.0)	4845 (36.5)	2196 (28.5)	7769 (58.5)	1654	971
SWAST	4982 (28.4)	5896 (33.6)	3748 (29.9)	8732 (49.8)	1899	1435
WMAS	9969 (44.4)	7652 (34.1)	3244 (26.0)	13,216 (58.9)	1644	959
YAS	1782 (18.7)	3268 (34.3)	2614 (33.7)	4396 (46.1)	1160	971
Total	57,134 (38.8)	53,623 (36.4)	28,473 (31.7)	85,623 (58.1)	13,922	9834

TABLE 72 Out-of-hospital cardiac arrest coverage by AEDs deployed in nursing and residential care homes

		By a nursing or residential care home only (ignoring registered AEDs)				By a nursing or residential care home if not by a registered AED				By a registered AED or a nursing or residential care home			
Service	Number of nursing and residential care homes	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency
EEAS	1994	1772	1772	0.0	88.9	1303	1303	0.0	65.3	2443	2443	0.0	122.5
EMAS	1745	3911	3911	0.0	224.1	1574	1574	0.0	90.2	7108	7108	0.0	407.3
IOWAS	113	83	83	0.0	73.5	14	14	0.0	12.4	128	128	0.0	113.2
LAS	1882	11,590	11,590	0.0	615.8	3880	3880	0.0	206.2	20,617	20,617	0.0	1095.5
NEAS	802	4439	4439	0.0	553.5	3643	3643	0.0	454.2	5348	5348	0.0	666.8
NWAS	2290	8023	8023	0.0	350.3	5069	5069	0.0	221.4	11,923	11,923	0.0	520.7
SCAS	1654	2144	2144	0.0	129.6	1199	1199	0.0	72.5	3943	3943	0.0	238.4
SECAmb	2174	4845	4845	0.0	222.9	2196	2196	0.0	101.0	7769	7769	0.0	357.4
SWAST	2272	5896	5896	0.0	259.5	3750	3750	0.0	165.1	8732	8732	0.0	384.3
WMAS	1970	7652	7652	0.0	388.4	3247	3247	0.0	164.8	13,216	13,216	0.0	670.9
YAS	1720	3268	3268	0.0	190.0	2614	2614	0.0	152.0	4396	4396	0.0	255.6
Total	18,616	53,623	53,623	0.0	288.0	28,489	28,489	0.0	153.0	85,623	85,623	0.0	460.0

Halls and community centres

TABLE 73 Number of OHCAs covered by halls and community centres

Service	Number (%) of OHCAs covered				Number of POIs that covered the OHCAs	
	Registered AEDs	By a POI only (ignoring registered AEDs)	By a POI if not by a registered AED	By a registered AED or a POI	By a POI (ignoring registered AEDs)	By a POI if not by a registered AED
EEAS	1140 (21.9)	1379 (26.5)	883 (21.7)	2023 (38.9)	793	501
EMAS	5534 (47.4)	3979 (34.1)	1521 (24.9)	7055 (60.5)	1328	661
IOWAS	114 (62.6)	70 (38.5)	5 (7.4)	119 (65.4)	24	5
LAS	16,737 (63.8)	11,993 (45.7)	3487 (36.7)	20,225 (77.1)	1636	1222
NEAS	1705 (15.0)	4722 (41.7)	3679 (38.2)	5384 (47.5)	855	713
NWAS	6854 (31.2)	6910 (31.4)	4141 (27.4)	10,999 (50.0)	1511	1093
SCAS	2744 (34.8)	2107 (26.7)	913 (17.8)	3657 (46.4)	740	375
SECAmb	5573 (42.0)	3758 (28.3)	1368 (17.8)	6941 (52.3)	1053	544
SWAST	4982 (28.4)	4889 (27.9)	2591 (20.6)	7575 (43.2)	1431	869
WMAS	9969 (44.4)	6434 (28.7)	2548 (20.4)	12,517 (55.8)	1375	763
YAS	1782 (18.7)	3293 (34.5)	2462 (31.7)	4246 (44.5)	1152	896
Total	57,134 (38.8)	49,534 (30.9)	23,598 (24.5)	80,741 (53.8)	11,898	7642

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TABLE 74 Out-of-hospital cardiac arrest coverage by AEDs deployed in halls and community centres

Service	Number of community halls and centres	By a community hall or centre only (ignoring registered AEDs)				By a community hall or centre if not by a registered AED				By a registered AED or a community hall or centre			
		Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency
EEAS	2125	1379	1379	0.0	64.9	883	883	0.0	41.6	2023	2023	0.0	95.2
EMAS	1994	3979	3979	0.0	199.5	1521	1521	0.0	76.2	7055	7055	0.0	353.8
IOWAS	54	70	70	0.0	129.6	5	5	0.0	9.3	119	119	0.0	220.4
LAS	1735	11,993	11,993	0.0	691.1	3488	3488	0.0	201.0	20,225	20,225	0.0	1165.7
NEAS	908	4722	4722	0.0	520.0	3679	3679	0.0	405.2	5384	5384	0.0	593.0
NWAS	1959	6910	6910	0.0	352.7	4145	4145	0.0	211.6	10,999	10,999	0.0	561.5
SCAS	1644	2107	2107	0.0	128.2	913	913	0.0	55.5	3657	3657	0.0	222.4
SECAmb	1465	3758	3758	0.0	256.5	1368	1368	0.0	93.4	6941	6941	0.0	473.8
SWAST	2014	4889	4889	0.0	242.8	2593	2593	0.0	128.7	7575	7575	0.0	376.1
WMAS	1890	6434	6434	0.0	340.4	2548	2548	0.0	134.8	12,517	12,517	0.0	662.2
YAS	1816	3293	3293	0.0	181.3	2464	2464	0.0	135.7	4246	4246	0.0	233.8
Total	17,604	49,534	49,534	0.0	281.4	23,607	23,607	0.0	134.1	80,741	80,741	0.0	458.7

Gyms, sports halls and leisure centres

TABLE 75 Number of OHCAs covered by gyms, sports halls and leisure centres

Service	Number (%) of OHCAs covered				Number of POIs that covered the OHCAs	
	Registered AEDs	By a POI only (ignoring registered AEDs)	By a POI if not by a registered AED	By a registered AED or a POI	By a POI only (ignoring registered AEDs)	By a POI if not by a registered AED
EEAS	1140 (21.9)	1015 (19.5)	711 (17.5)	1851 (35.6)	626	451
EMAS	5534 (47.4)	2885 (24.7)	1065 (17.4)	6600 (56.6)	1004	487
IOWAS	114 (62.6)	15 (8.2)	2 (2.9)	116 (63.7)	5	2
LAS	16,737 (63.8)	13,865 (52.8)	3775 (39.7)	20,515 (78.2)	2360	1496
NEAS	1705 (15.0)	3185 (28.1)	2545 (26.5)	4250 (37.5)	617	530
NWAS	6854 (31.2)	7052 (32.1)	4055 (26.8)	10,913 (49.6)	1767	1197
SCAS	2744 (34.8)	1875 (23.8)	868 (16.9)	3614 (45.8)	696	395
SECAmb	5573 (42.0)	3127 (23.6)	1112 (14.4)	6685 (50.4)	977	486
SWAST	4982 (28.4)	3828 (21.8)	2435 (19.4)	7417 (42.3)	1108	824
WMAS	9969 (44.4)	5636 (25.1)	2102 (16.8)	12,075 (53.8)	1234	667
YAS	1782 (18.7)	2675 (28.0)	2002 (25.8)	3788 (39.7)	983	791
Total	57,134 (38.8)	45,158 (30.7)	20,672 (22.9)	77,824 (52.8)	11,377	7326

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TABLE 76 Out-of-hospital cardiac arrest coverage by AEDs deployed in gyms, sports halls and leisure centres

		By a gym, sports hall or leisure centre only (ignoring registered AEDs)				By a gym, sports hall or leisure centre if not by a registered AED				By a registered AED or a gym, sports hall or leisure centre			
Service	Number of gyms, sports hall and leisure centres	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency
EEAS	1961	1015	656	35.4	33.5	711	452	36.4	23.0	1851	1184	36.0	60.4
EMAS	1755	2885	1794	37.8	102.2	1066	685	35.7	39.0	6600	4116	37.6	234.5
IOWAS	25	15	9	40.0	36.0	2	2	0.0	8.0	116	79	31.9	316.0
LAS	2836	13,865	7299	47.4	257.4	3778	1925	49.0	67.9	20,515	10,633	48.2	374.9
NEAS	699	3185	1990	37.5	284.7	2545	1577	38.0	225.6	4250	2620	38.4	374.8
NWAS	2306	7052	4681	33.6	203.0	4059	2659	34.5	115.3	10,913	7188	34.1	311.7
SCAS	1701	1875	1285	31.5	75.5	870	589	32.3	34.6	3614	2494	31.0	146.6
SECAmb	1432	3127	1967	37.1	137.4	1112	689	38.0	48.1	6685	4180	37.5	291.9
SWAST	1537	3828	2663	30.4	173.3	2435	1659	31.9	107.9	7417	5079	31.5	330.4
WMAS	1700	5636	3824	32.2	224.9	2106	1410	33.0	82.9	12,075	8110	32.8	477.1
YAS	1723	2675	1728	35.4	100.3	2006	1275	36.4	74.0	3788	2391	36.9	138.8
Total	17,675	45,158	27,896	38.2	157.8	20,690	12,922	37.5	73.1	77,824	48,074	38.2	272.0

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Supermarket chains

TABLE 77 Number of OHCAs covered by supermarket chains

Service	Number (%) of OHCAs covered				Number of POIs that covered the OHCAs	
	Registered AEDs	By a POI only (ignoring registered AEDs)	By a POI if not by a registered AED	By a registered AED or a POI	By a POI only (ignoring registered AEDs)	By a POI if not by a registered AED
EEAS	1140 (21.9)	744 (14.3)	468 (11.5)	1608 (30.9)	396	252
EMAS	5534 (47.4)	1894 (16.2)	459 (7.5)	5993 (51.4)	552	233
IOWAS	114 (62.6)	56 (30.8)	3 (4.4)	117 (64.3)	16	3
LAS	16,737 (63.8)	6866 (26.2)	1592 (16.8)	18,332 (69.9)	650	495
NEAS	1705 (15.0)	1945 (17.2)	1426 (14.8)	3131 (27.6)	289	244
NWAS	6854 (31.2)	3922 (17.8)	1897 (12.5)	8752 (39.8)	763	457
SCAS	2744 (34.8)	1537 (19.5)	639 (12.4)	3383 (42.9)	402	223
SECAmb	5573 (42.0)	2365 (17.8)	668 (8.7)	6242 (47.0)	513	233
SWAST	4982 (28.4)	3323 (18.9)	1797 (14.3)	6781 (38.7)	722	502
WMAS	9969 (44.4)	3602 (16.0)	947 (7.6)	10,919 (48.6)	602	281
YAS	1782 (18.7)	1659 (17.4)	1129 (14.6)	2912 (30.5)	494	371
Total	57,134 (38.8)	27,913 (18.9)	11,025 (12.2)	68,170 (46.3)	5399	3284

TABLE 78 Out-of-hospital cardiac arrest coverage by AEDs deployed in supermarket chains

Service	Number of supermarkets	By a supermarket chain only (ignoring registered AEDs)				By a supermarket chain if not by a registered AED				By a registered AED or a supermarket chain			
		Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency
EEAS	738	744	464	37.6	62.9	468	283	39.5	38.3	1608	1007	37.4	136.4
EMAS	692	1894	1157	38.9	167.2	459	298	35.1	43.1	5993	3693	38.4	533.7
IOWAS	24	56	35	37.5	145.8	3	2	33.3	8.3	117	77	34.2	320.8
LAS	667	6866	3645	46.9	546.5	1595	810	49.2	121.4	18,332	9494	48.2	1423.4
NEAS	281	1945	1192	38.7	424.2	1426	869	39.1	309.3	3131	1913	38.9	680.8
NWAS	842	3922	2655	32.3	315.3	1898	1263	33.5	150.0	8752	5772	34.0	685.5
SCAS	653	1537	1059	31.1	162.2	639	430	32.7	65.8	3383	2311	31.7	353.9
SECAmb	536	2365	1510	36.2	281.7	669	415	38.0	77.4	6242	3861	38.1	720.3
SWAST	715	3323	2295	30.9	321.0	1799	1210	32.7	169.2	6781	4652	31.4	650.6
WMAS	644	3602	2528	29.8	392.5	950	645	32.1	100.2	10,919	7320	33.0	1136.6
YAS	637	1659	1051	36.6	165.0	1130	713	36.9	111.9	2912	1818	37.6	285.4
Total	6429	27,913	17,591	37.0	273.6	11,036	6938	37.1	107.9	68,170	41,918	38.5	652.0

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State first, primary and infant schools

TABLE 79 Number of OHCAs covered by state first, primary and infant schools

Service	Number (%) of OHCAs covered				Number of POIs that covered the OHCAs	
	Registered AEDs	By a POI only (ignoring registered AEDs)	BY a POI if not by a registered AED	BY a registered AED or a POI	By a POI only (ignoring registered AEDs)	BY a POI if not by a registered AED
EEAS	1140 (21.9)	1514 (29.1)	1076 (26.5)	2216 (42.6)	865	641
EMAS	5534 (47.4)	3866 (33.1)	1594 (26.1)	7128 (61.1)	1272	705
IOWAS	114 (62.6)	35 (19.2)	11 (16.2)	125 (68.7)	19	7
LAS	16,737 (63.8)	12,788 (48.7)	3991 (42.0)	20,728 (79.0)	1710	1315
NEAS	1705 (15.0)	4322 (38.1)	3557 (37.0)	5262 (46.4)	766	676
NWAS	6854 (31.2)	8735 (39.7)	5078 (33.6)	11,933 (54.3)	2025	1416
SCAS	2744 (34.8)	2065 (26.2)	1094 (21.3)	3838 (48.7)	738	468
SECAmb	5573 (42.0)	3376 (25.4)	1589 (20.6)	7162 (54.0)	982	618
SWAST	4982 (28.4)	4631 (26.4)	2938 (23.4)	7920 (45.2)	1349	957
WMAS	9969 (44.4)	7649 (34.1)	3630 (29.1)	13,600 (60.6)	1512	1003
YAS	1782 (18.7)	3184 (33.4)	2467 (31.8)	4252 (44.6)	1161	946
Total	57,134 (38.8)	52,165 (35.4)	27,025 (30.0)	84,164 (57.1)	12,399	8752

TABLE 80 Out-of-hospital cardiac arrest coverage by AEDs deployed in state first, primary and infant schools

Service	Number of state first, primary and infant schools	By a state state first, primary or infant school only (ignoring registered AEDs)				By a state first, primary or infant school if not by a registered AED				By a registered AED or a state first, primary or infant school			
		Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency
EEAS	1986	1514	330	78.2	16.6	1076	236	78.1	11.9	2216	487	78.0	24.5
EMAS	1729	3866	819	78.8	47.4	1594	360	77.4	20.8	7128	1511	78.8	87.4
IOWAS	39	35	9	74.3	23.1	11	3	72.7	7.7	125	26	79.2	66.7
LAS	1803	12,788	2413	81.1	133.8	3991	684	82.9	37.9	20,728	3982	80.8	220.9
NEAS	741	4322	973	77.5	131.3	3557	796	77.6	107.4	5262	1218	76.9	164.4
NWAS	2439	8735	2093	76.0	85.8	5079	1186	76.6	48.6	11,933	2874	75.9	117.8
SCAS	1552	2065	504	75.6	32.5	1094	262	76.1	16.9	3838	987	74.3	63.6
SECAmb	1258	3376	726	78.5	57.7	1589	329	79.3	26.2	7162	1646	77.0	130.8
SWAST	1607	4631	1133	75.5	70.5	2938	692	76.4	43.1	7920	1948	75.4	121.2
WMAS	1755	7649	1805	76.4	102.8	3631	835	77.0	47.6	13,600	3321	75.6	189.2
YAS	1744	3184	681	78.6	39.0	2470	530	78.5	30.4	4252	908	78.6	52.1
Total	16,653	52,165	11,486	78.0	69.0	27,030	5913	78.1	21.9	84,164	18,908	77.5	113.5

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State secondary schools

TABLE 81 Number of OHCAs covered by state secondary schools

Service	Number (%) of OHCAs covered				Number of POIs that covered the OHCAs	
	Registered AEDs	By a POI only (ignoring registered AEDs)	By a POI if not by a registered AED	By a registered AED or a POI	By a POI only (ignoring registered AEDs)	By a POI if not by a registered AED
EEAS	1140 (21.9)	303 (5.8)	240 (5.9)	1380 (26.5)	183	149
EMAS	5534 (47.4)	644 (5.5)	211 (3.5)	5745 (49.2)	237	102
IOWAS	114 (62.6)	8 (4.4)	2 (2.9)	116 (63.7)	6	2
LAS	16,737 (63.8)	3877 (14.8)	1129 (11.9)	17,866 (68.1)	479	376
NEAS	1705 (15.0)	556 (4.9)	470 (4.9)	2175 (19.2)	151	139
NWAS	6854 (31.2)	1479 (6.7)	804 (5.3)	7658 (34.8)	394	244
SCAS	2744 (34.8)	473 (6.0)	264 (5.1)	3008 (38.1)	165	105
SECAmb	5573 (42.0)	580 (4.4)	246 (3.2)	5820 (43.9)	193	110
SWAST	4982 (28.4)	849 (4.8)	575 (4.6)	5557 (31.7)	257	203
WMAS	9969 (44.4)	1665 (7.4)	670 (5.4)	10,639 (47.4)	352	195
YAS	1782 (18.7)	485 (5.1)	373 (4.8)	2155 (22.6)	207	166
Total	57,134 (38.8)	10,919 (7.4)	4984 (64.2)	62,119 (42.2)	2624	1791

TABLE 82 Out-of-hospital cardiac arrest coverage by AEDs deployed in state secondary schools

		By a state secondary schools only (ignoring registered AEDs)				By a state secondary schools if not by a registered AED				By a registered AED or a state secondary schools			
Service	Number of state secondary schools	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency
EEAS	397	303	50	83.5	12.6	240	38	84.2	9.6	1380	289	79.1	72.8
EMAS	319	644	137	78.7	42.9	211	50	76.3	15.7	5745	1201	79.1	376.5
IOWAS	8	8	0	100.0	0.0	2	0	100.0	0.0	116	23	80.2	287.5
LAS	514	3877	717	81.5	139.5	1129	193	82.9	37.5	17,866	3491	80.5	679.2
NEAS	153	556	144	74.1	94.1	470	116	75.3	75.8	2175	538	75.3	351.6
NWAS	466	1479	366	75.3	78.5	804	202	74.9	43.3	7658	1890	75.3	127.8
SCAS	290	473	129	72.7	44.5	264	73	72.3	25.2	3008	798	73.5	275.2
SECAmb	254	580	134	76.9	52.8	247	61	75.3	24.0	5820	1378	76.3	542.5
SWAST	305	849	208	75.5	68.2	575	129	77.6	42.3	5557	1385	75.1	163.1
WMAS	424	1665	397	76.2	93.6	670	137	79.6	32.3	10,639	2623	75.3	157.5
YAS	323	485	97	80.0	30.0	373	77	79.4	23.8	2155	455	78.9	93.8
Total	3453	10,919	2379	78.2	68.9	4985	1076	78.4	31.2	62,119	14,071	77.3	407.5

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State first, primary, infant and state secondary schools

TABLE 83 Number of OHCAs covered by all state schools

Service	Number (%) of OHCAs covered				Number of POIs that covered the OHCAs	
	Registered AEDs	By a POI only (ignoring registered AEDs)	By a POI if not by a registered AED	By a registered AED or a POI	By a POI only (ignoring registered AEDs)	By a POI if not by a registered AED
EEAS	1140 (21.9)	1734 (33.3)	1251 (24.0)	2391 (46.0)	991	743
EMAS	5534 (47.4)	4225 (36.2)	1732 (14.8)	7266 (62.3)	1448	774
IOWAS	114 (62.6)	41 (22.5)	13 (7.1)	127 (69.8)	23	9
LAS	16,737 (63.8)	14,252 (54.3)	4529 (17.3)	21,266 (81.1)	2009	1497
NEAS	1705 (15.0)	4615 (40.7)	3814 (33.7)	5519 (48.7)	877	777
NWAS	6854 (31.2)	9542 (43.4)	5568 (25.3)	12,422 (56.5)	2207	1558
SCAS	2744 (34.8)	2361 (29.9)	1274 (16.2)	4018 (51.0)	863	542
SECAmb	5573 (42.0)	3751 (28.3)	1762 (13.3)	7335 (55.3)	1120	698
SWAST	4982 (28.4)	5187 (29.6)	3334 (19.0)	8316 (47.4)	1551	1123
WMAS	9969 (44.4)	8603 (38.3)	4045 (18.0)	14,014 (62.4)	1739	1119
YAS	1782 (18.7)	3470 (36.4)	2695 (28.3)	4477 (46.9)	1308	1062
Total	57,134 (38.8)	57,781 (39.2)	30,017 (20.4)	87,151 (59.2)	14,136	9902

TABLE 84 Out-of-hospital cardiac arrest coverage by AEDs deployed in all state schools

Service	Number of state schools	By a state school only (ignoring registered AEDs)				By a state school if not by a registered AED				By a registered AED or a state school			
		Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency	Assumed coverage	Actual coverage	Coverage loss	Coverage efficiency
EEAS	397	1734	360	79.2	90.7	1251	258	79.4	65.0	2391	509	78.7	128.2
EMAS	319	4225	893	78.9	279.9	1732	392	77.4	122.9	7266	1543	78.8	483.7
IOWAS	8	41	9	78.0	112.5	13	3	76.9	37.5	127	26	79.5	325.0
LAS	514	14,252	2688	81.1	523.0	4529	784	82.7	152.5	21,266	4082	80.8	794.2
NEAS	153	4615	1040	77.5	679.7	3814	853	77.6	557.5	5519	1275	76.9	833.3
NWAS	466	9542	2313	75.6	496.4	5568	1319	76.3	283.0	12,422	3007	75.8	645.3
SCAS	290	2361	590	75.0	203.4	1274	318	75.0	109.7	4018	1043	74.0	359.7
SECAmb	254	3751	806	78.5	317.3	1762	369	79.1	145.3	7335	1686	77.0	663.8
SWAST	305	5187	1266	75.6	415.1	3334	778	76.7	255.1	8316	2034	75.5	666.9
WMAS	424	8603	2025	76.5	477.6	4045	919	77.3	216.7	14,014	3405	75.7	803.1
YAS	323	3470	740	78.7	229.1	2695	580	78.5	179.6	4477	958	78.6	296.6
Total	3453	57,781	12,730	78.0	368.7	30,017	6573	78.1	190.4	87,151	19,568	77.5	566.7

Appendix 10 Out-of-hospital cardiac arrest coverage gains and coverage levels using optimisation and POI approaches in English ambulance services

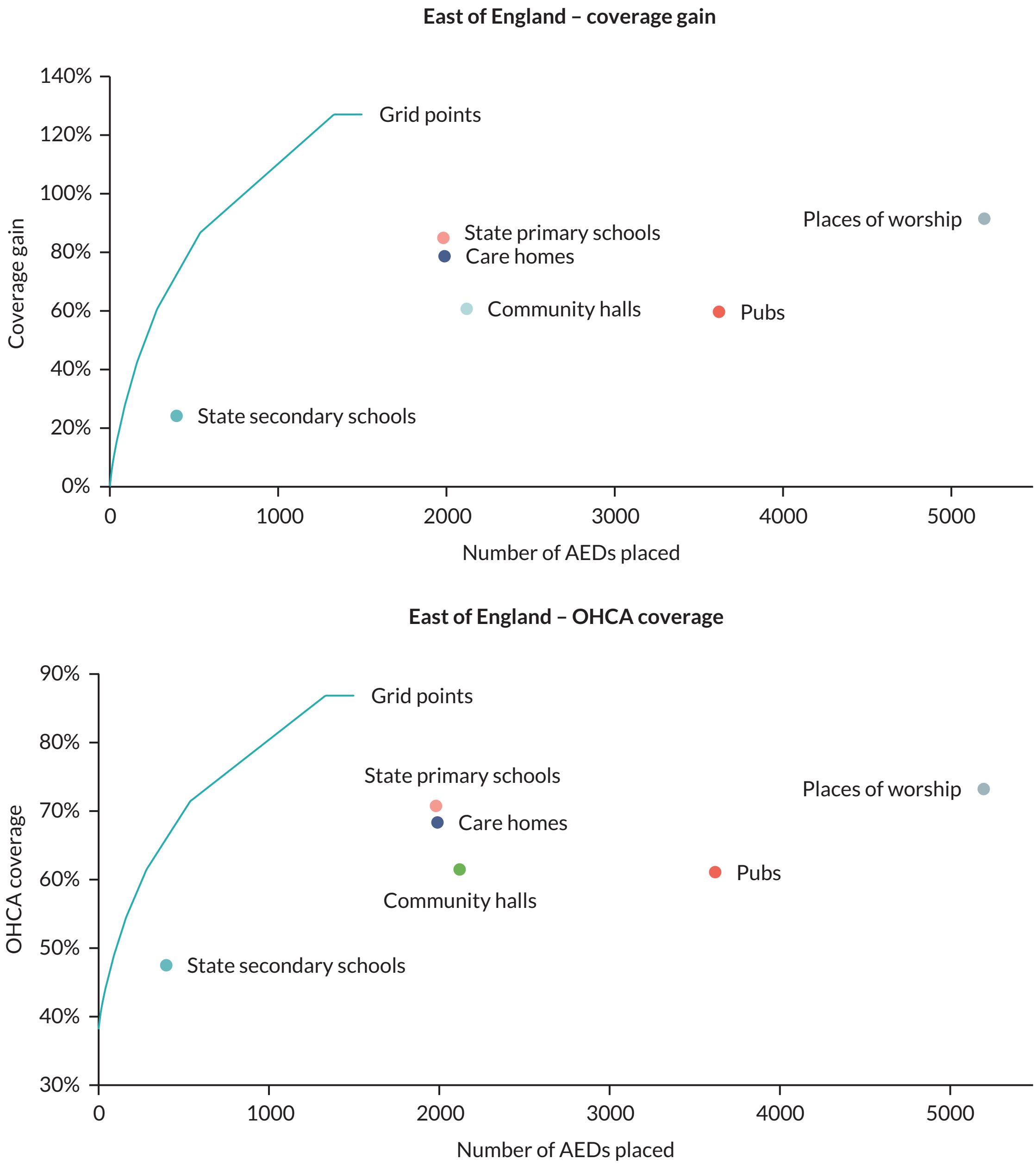

FIGURE 23 Comparison of OHCA coverage gains and coverage levels using optimisation and POI approaches in region served by EEAS.

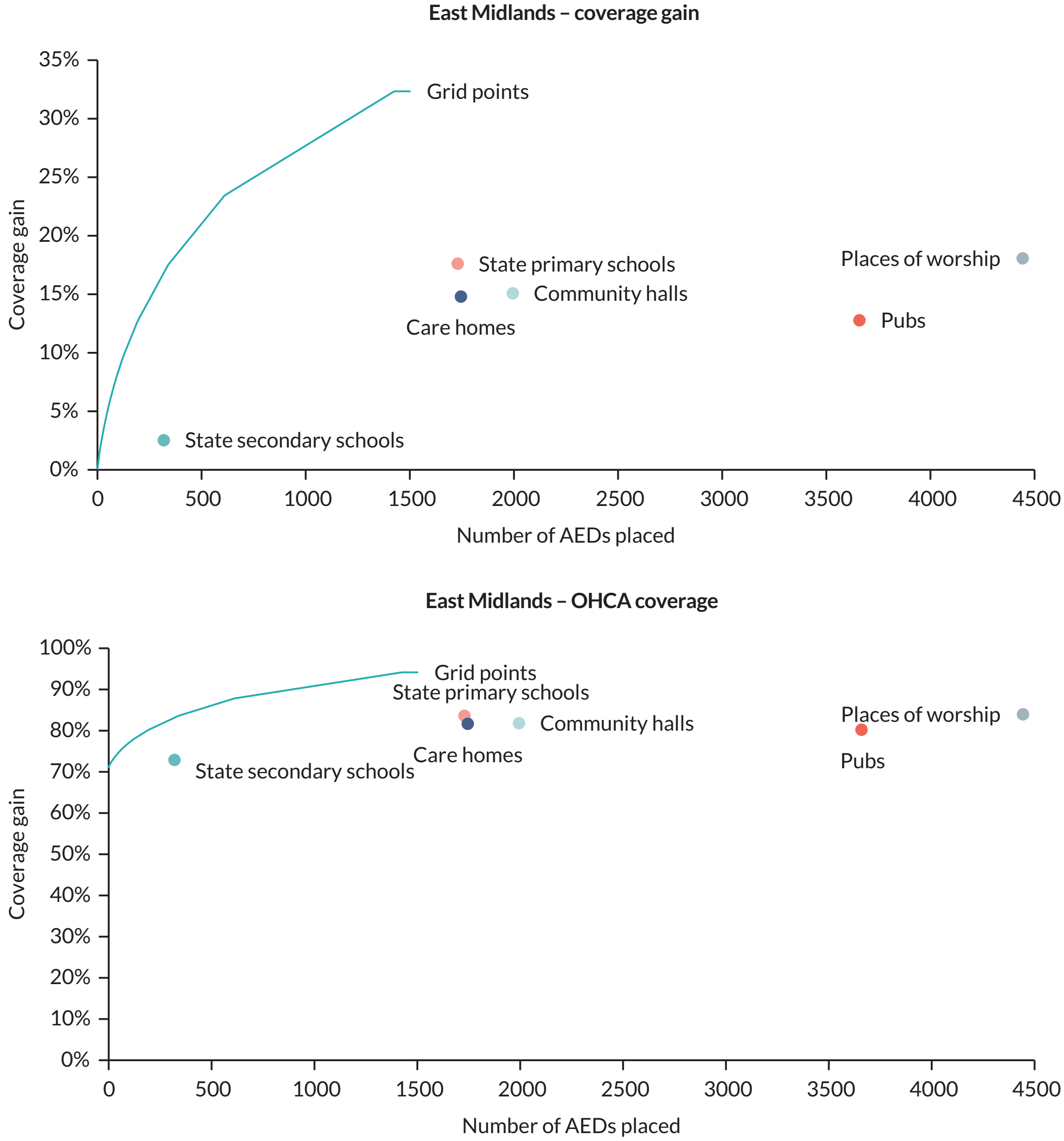

FIGURE 24 Comparison of OHCA coverage gains and coverage levels using optimisation and POI approaches in region served by EMAS.

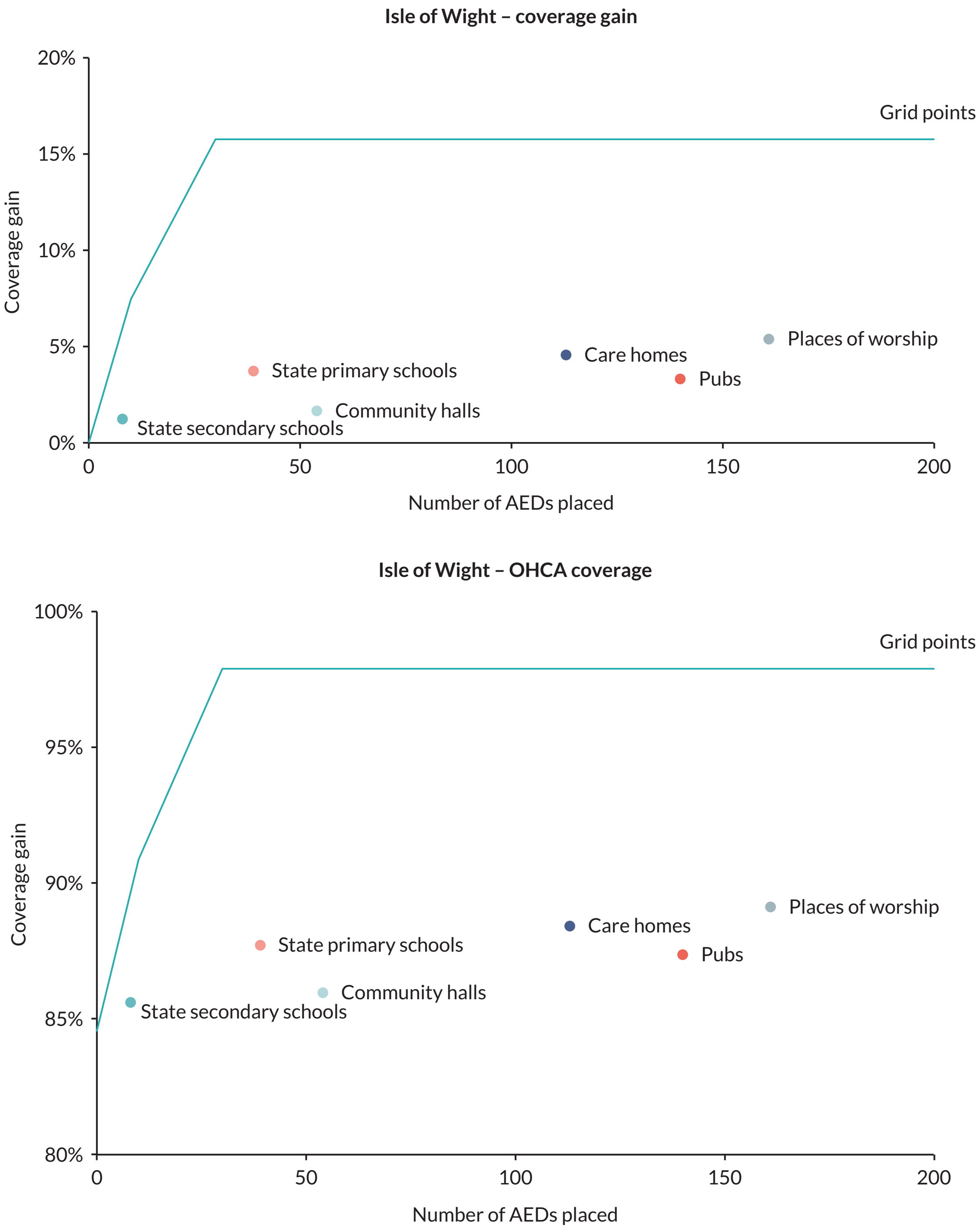

FIGURE 25 Comparison of OHCA coverage gains and coverage levels using optimisation and POI approaches in region served by IOWAS.

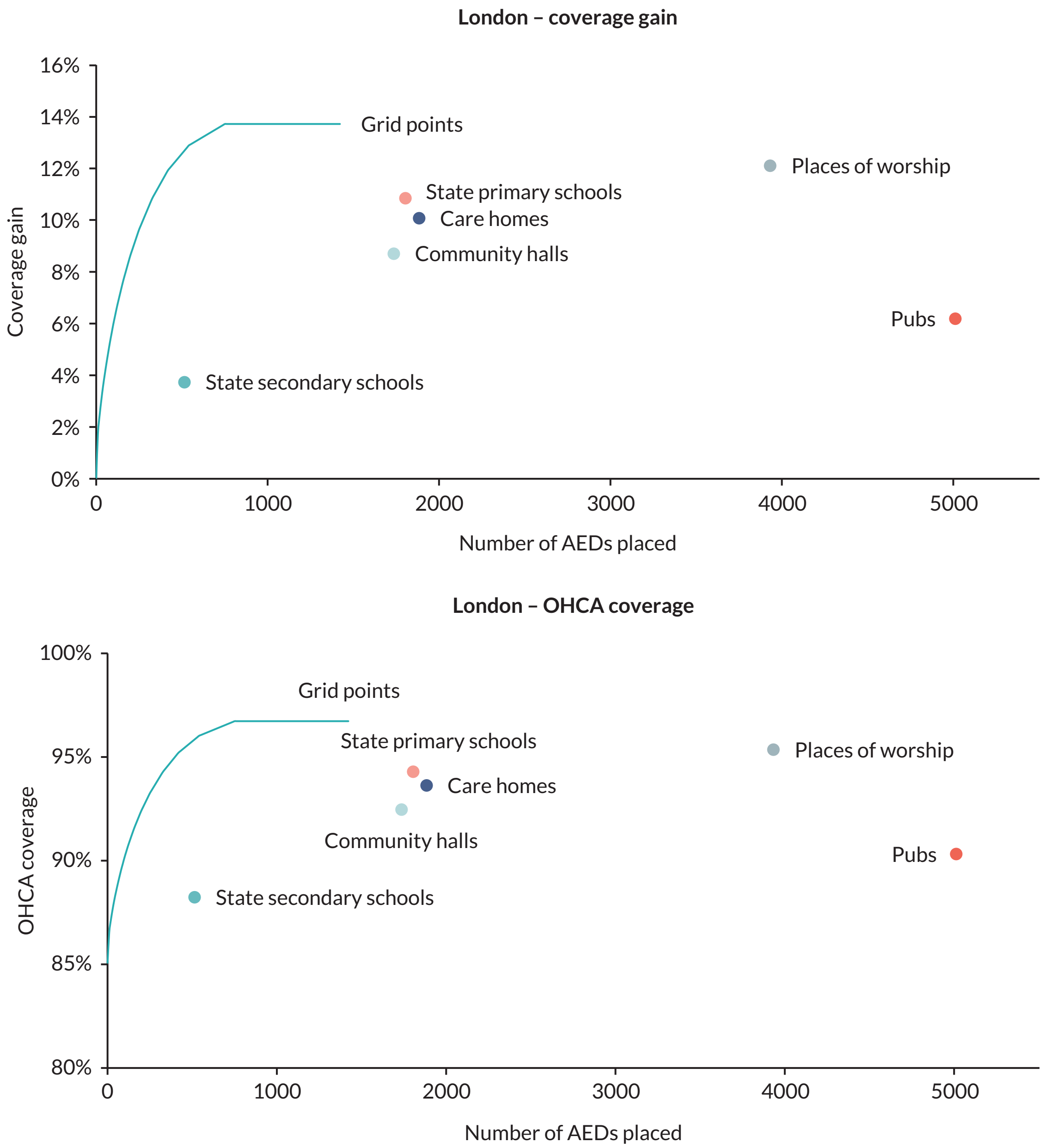

FIGURE 26 Comparison of OHCA coverage gains and coverage levels using optimisation and POI approaches in region served by LAS.

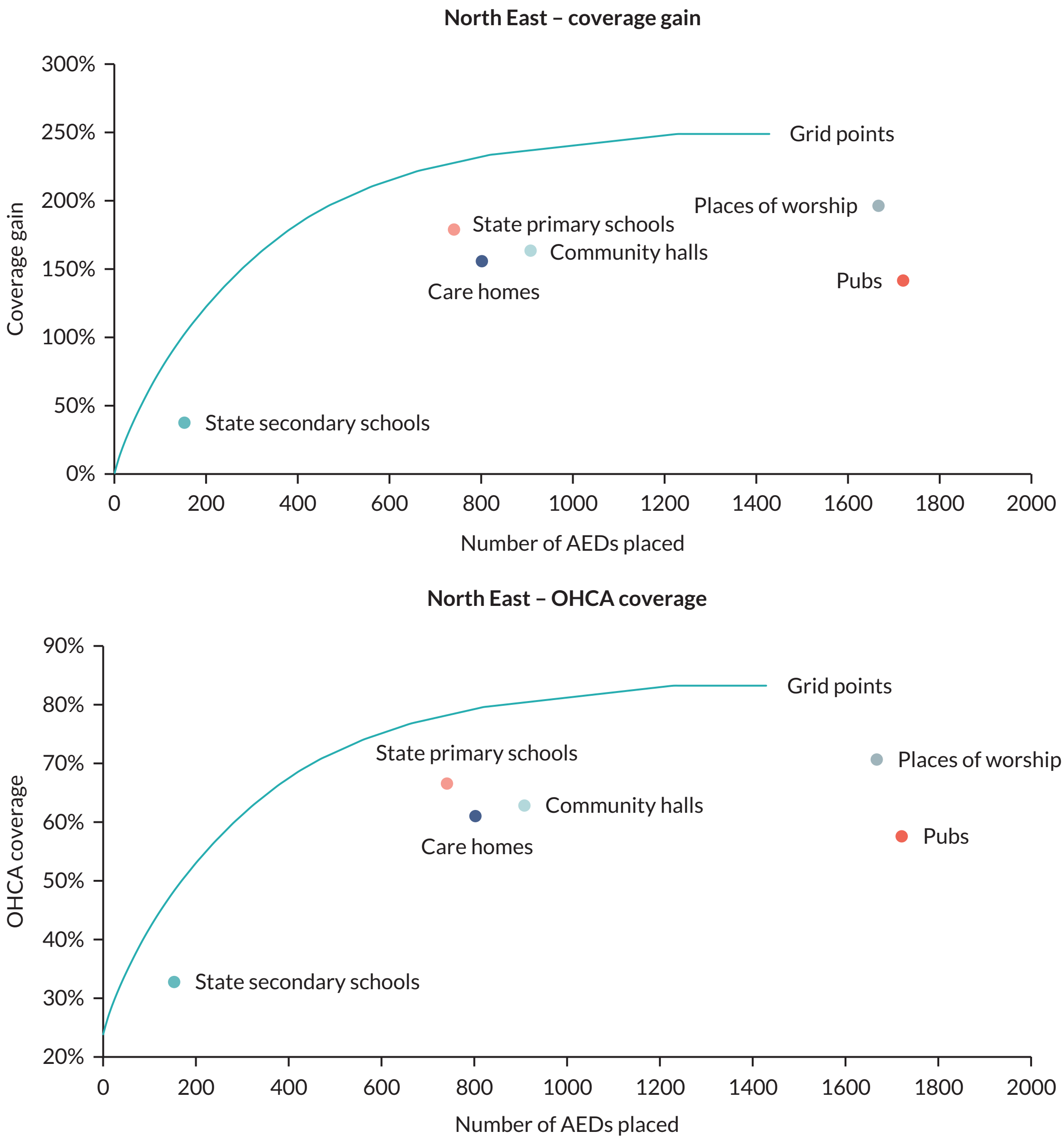

FIGURE 27 Comparison of OHCA coverage gains and coverage levels using optimisation and POI approaches in region served by NEAS.

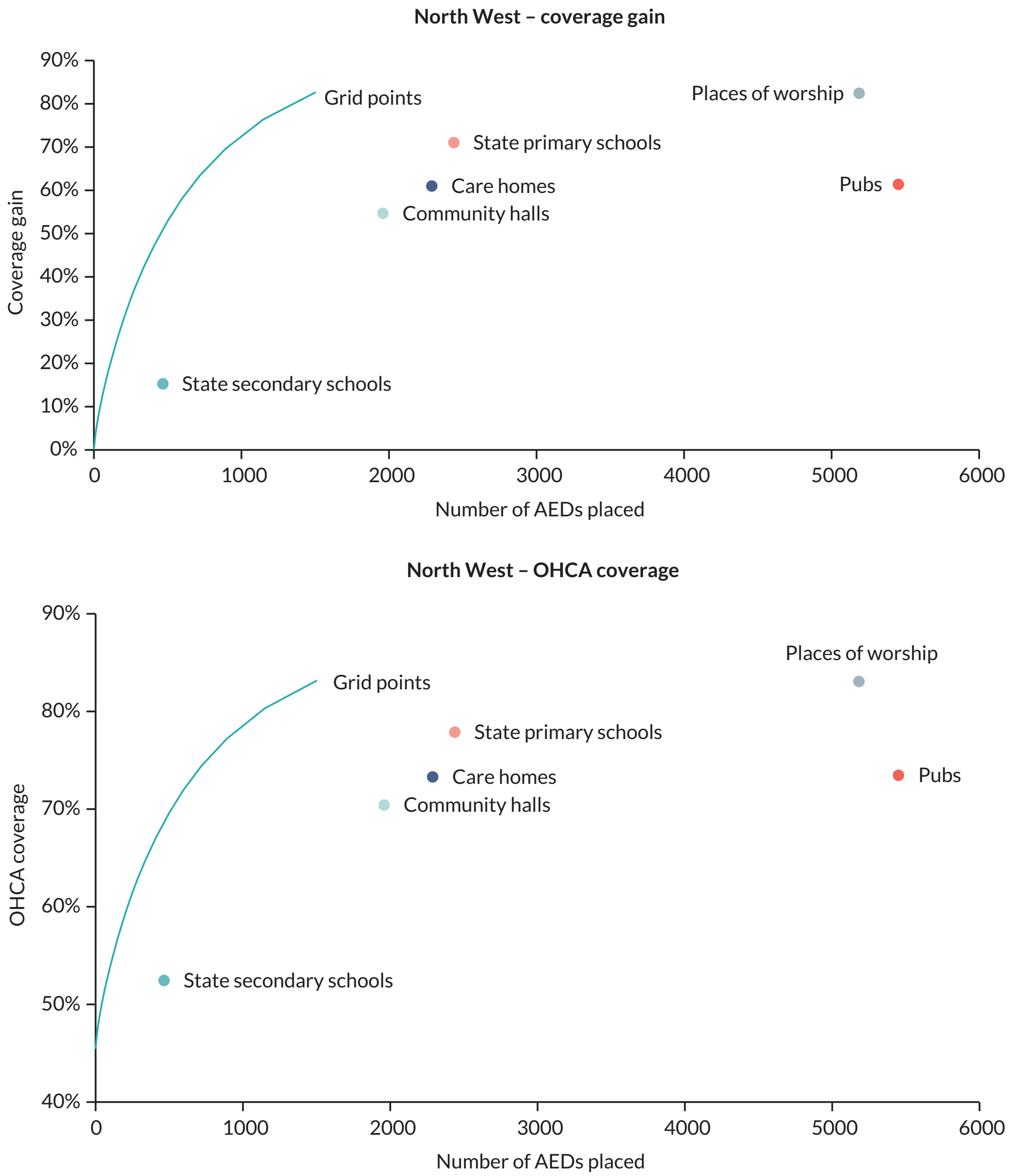

FIGURE 28 Comparison of OHCA coverage gains and coverage levels using optimisation and POI approaches in region served by NWAS.

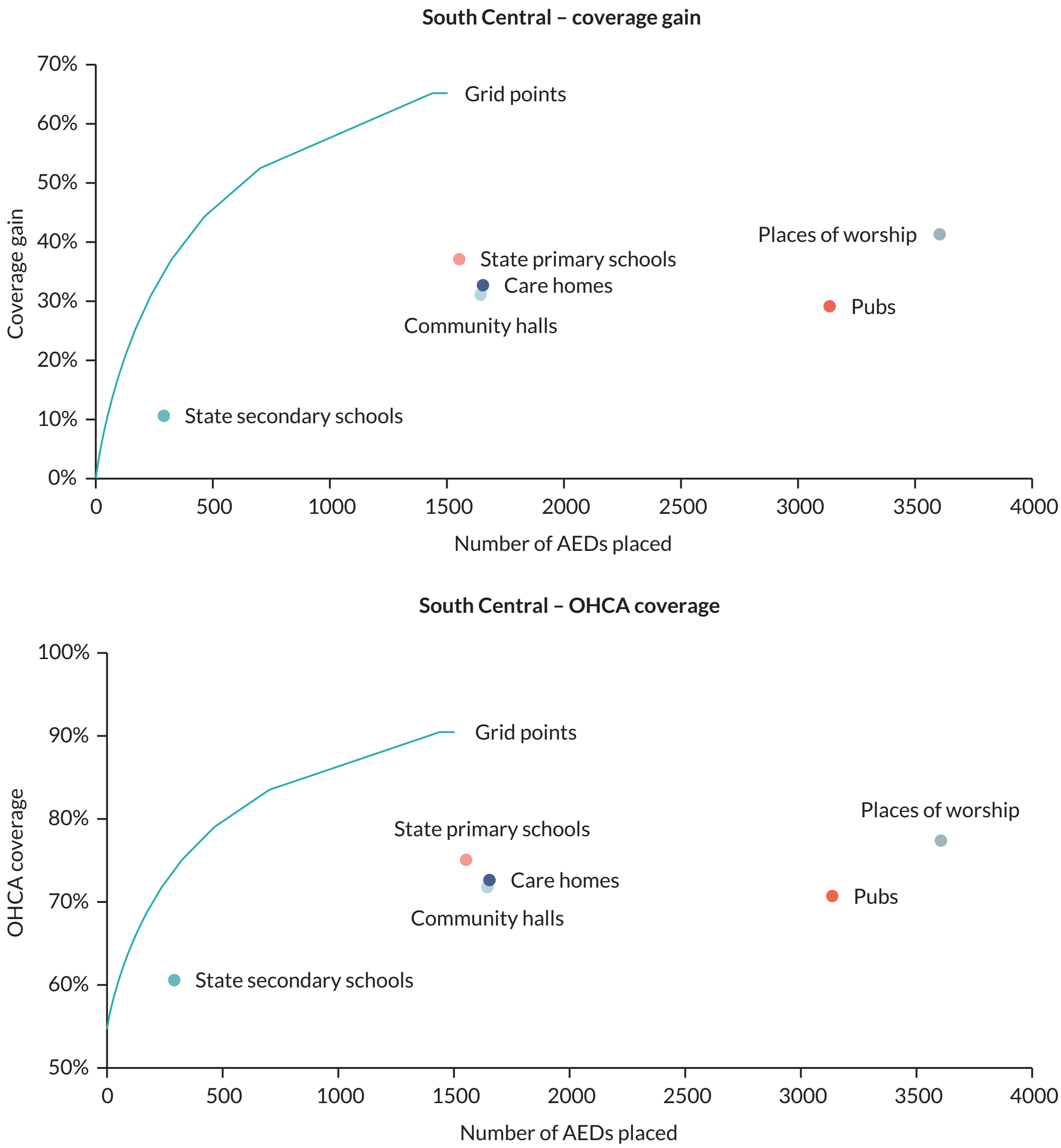

FIGURE 29 Comparison of OHCA coverage gains and coverage levels using optimisation and POI approaches in region served by SCAS.

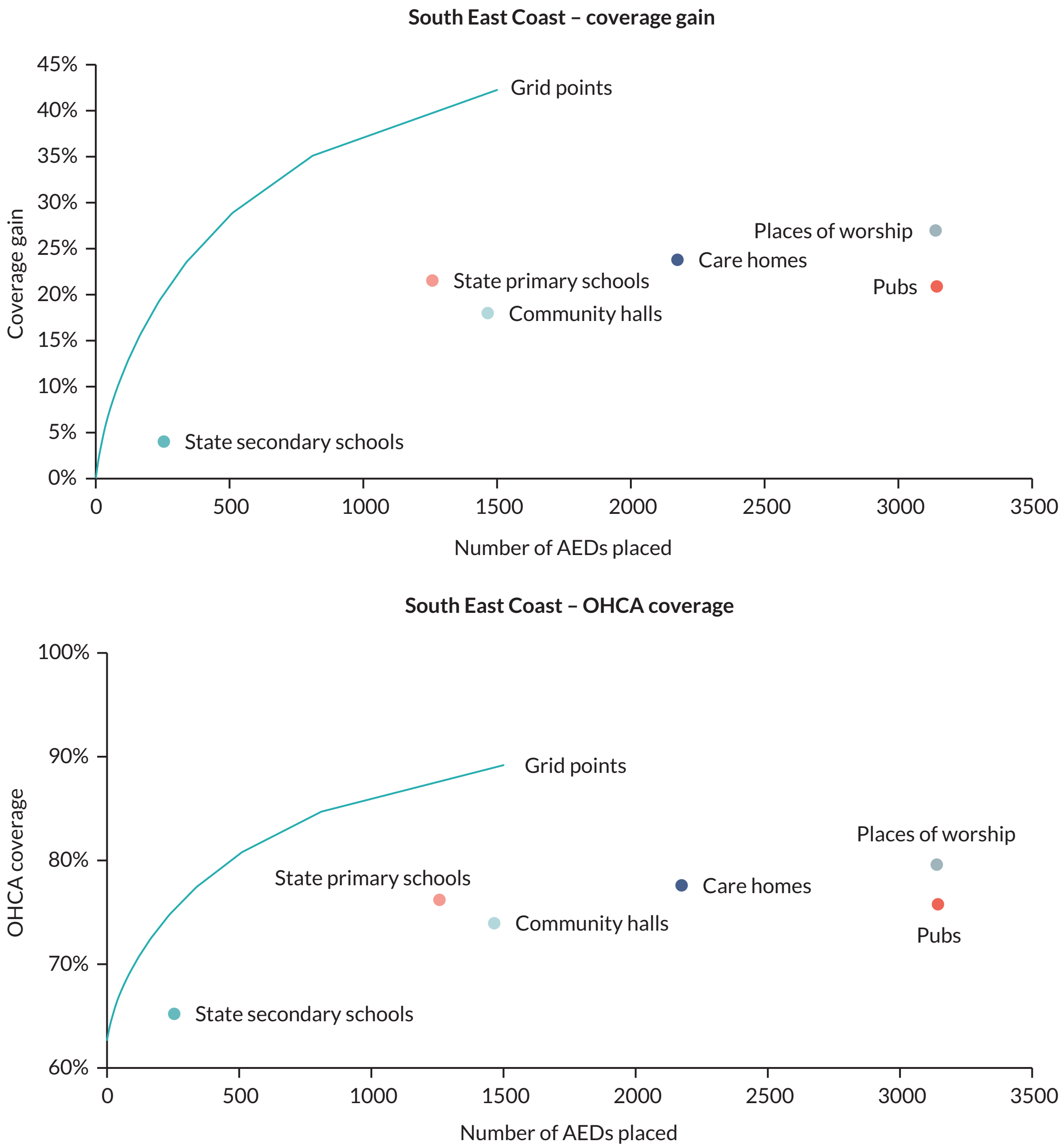

FIGURE 30 Comparison of OHCA coverage gains and coverage levels using optimisation and POI approaches in region served by SECAmb.

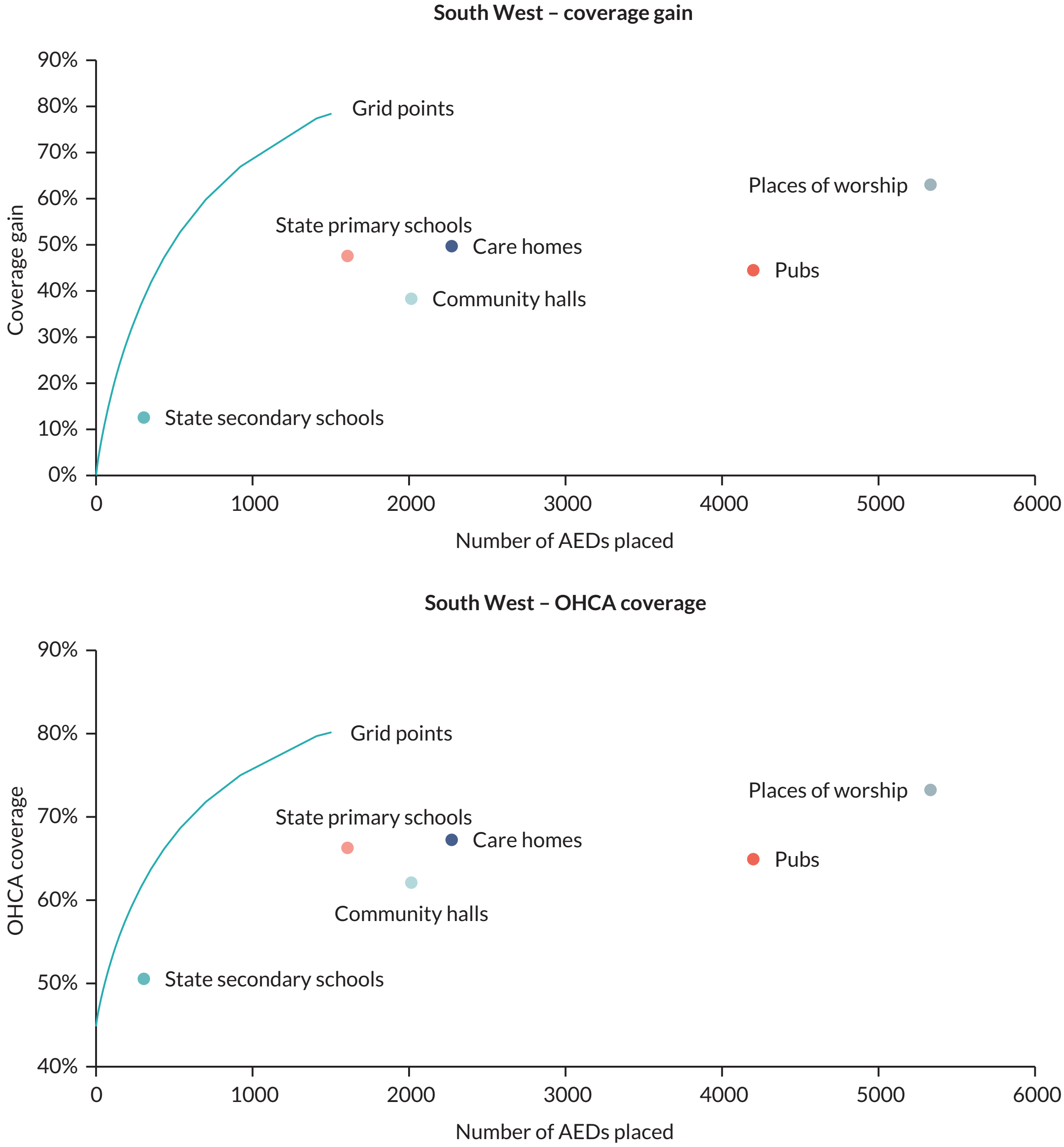

FIGURE 31 Comparison of OHCA coverage gains and coverage levels using optimisation and POI approaches in region served by SWAST.

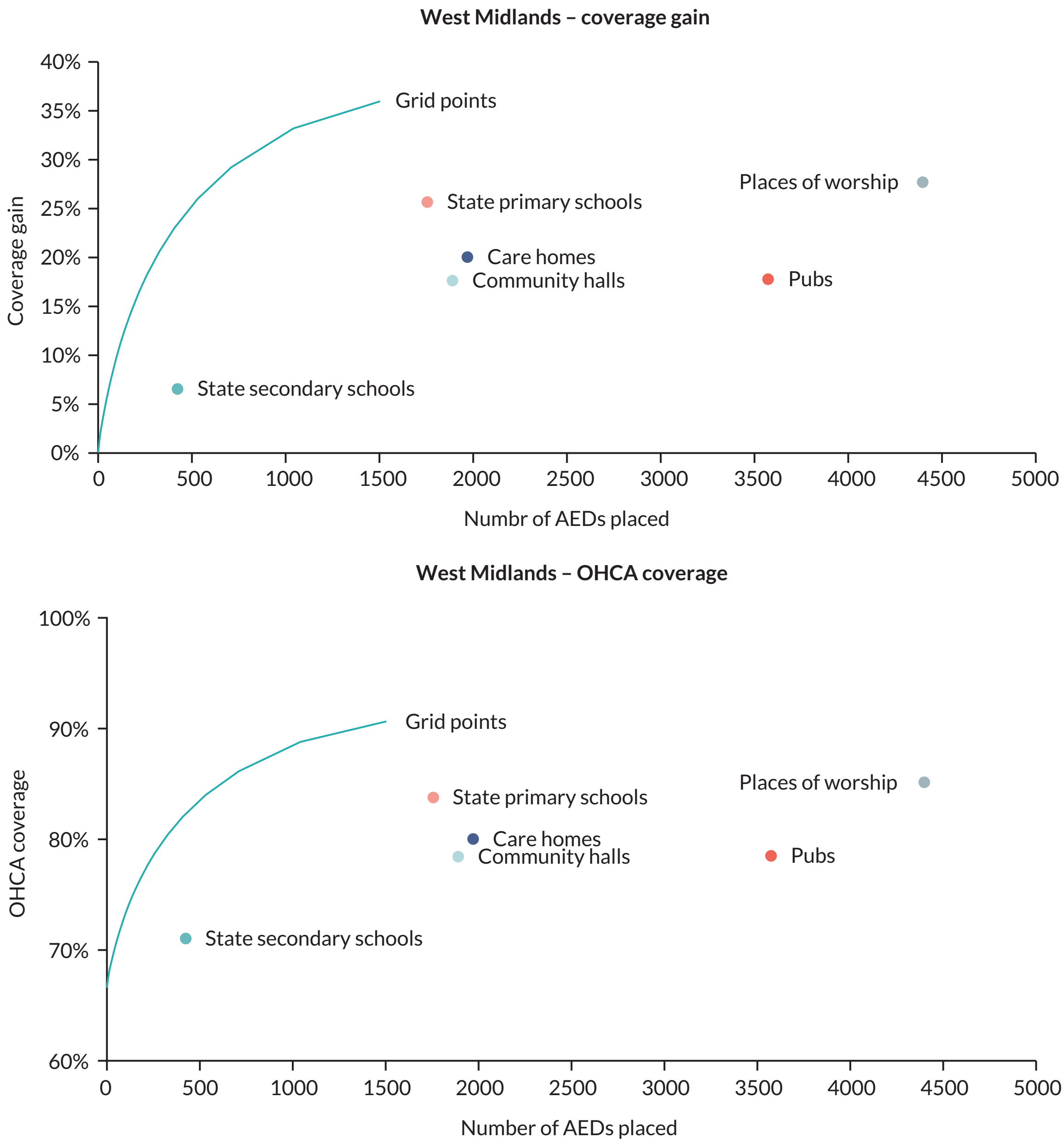

FIGURE 32 Comparison of OHCA coverage gains and coverage levels using optimisation and POI approaches in region served by WMAS.

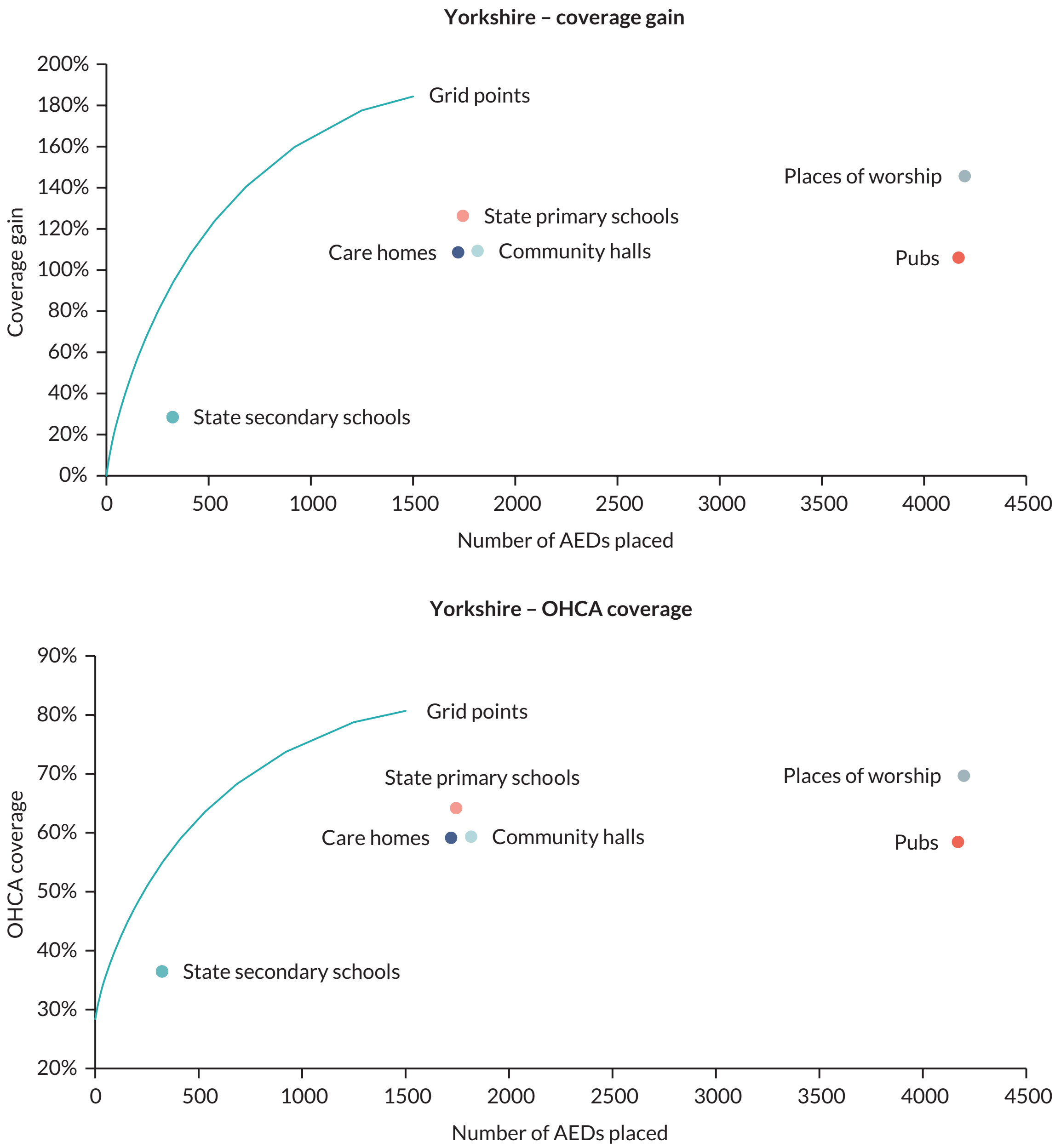

FIGURE 33 Comparison of OHCA coverage gains and coverage levels using optimisation and POI approaches in region served by YAS.

Appendix 11 Additional results from the cost-effectiveness analysis

TABLE 85 Results of deterministic (one way and multiway) sensitivity analyses

Parameter	Parameter value	ICER (£ per QALY)	ICER (£ per LYG)	Difference (base : base-case ICER) (%)
AED is available given current AED placement (base-case value)				
Base-case value + 10%	0.156	32,767	19,097	1.08
Base-case value − 10%	0.127	32,104	18,710	−0.97
AED being available given AED availability under alternative placement (base-case value)				
Base-case value + 10%	0.455	31,580	18,405	−2.58
Base-case value − 10%	0.372	33,557	19,557	3.51
AED being used if AED is available				
Base-case value	0.144	0	0	
Base-case value + 10%	0.159	31,841	18,557	−1.78
Base-case value − 10%	0.130	33,124	19,305	2.18
Patient arrives at hospital alive given that AED was used (base-case value)				
Base-case value + 10%	0.272	32,113	18,706	−0.94
Base-case value − 10%	0.223	32,906	19,193	1.51
Patient arrives at hospital alive given that AED was not used (base-case value)				
Base-case value + 10%	0.217	32,090	18,716	−1.01
Base-case value − 10%	0.178	32,670	19,030	0.78
Patient is discharged from hospital alive given that AED was used (base-case value)				
Base-case value + 10%	0.487	30,363	17,703	−6.34
Base-case value − 10%	0.398	35,710	20,797	10.15
Patient is discharged from hospital alive given that AED was not used (base-case value)				
Base-case value + 10%	0.346	34,071	19,850	5.10
Base-case value − 10%	0.283	31,148	18,158	−3.92
Same as base-case value for 'Patient is discharged from hospital alive given that AED was used'	0.443	44,963	26,135	38.70

continued

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TABLE 85 Results of deterministic (one way and multiway) sensitivity analyses (*continued*)

Parameter	Parameter value	ICER (£ per QALY)	ICER (£ per LYG)	Difference (base : base-case ICER) (%)
Acquisition and installation cost for an AED unit (£)				
Base-case value + 25%	1049	33,713	19,648	3.99
Base-case value − 25%	630	31,124	18,139	−3.99
Cost of in-hospital post-cardiac-arrest care if patient is discharged alive (£)				
Base-case value + 25%	53,023	35,286	20,565	8.85
Base-case value − 25%	31,814	29,550	17,222	−8.85
Cost of in-hospital post-cardiac-arrest care if patient dies before discharge (£)				
Base-case value + 25%	19,505	32,474	18,926	0.17
Base-case value − 25%	11,703	32,363	18,861	−0.17
Cost of emergency care, patient dead on arrival (£)				
Base-case value + 25%	898	32,367	18,864	−0.16
Base-case value − 25%	539	32,469	18,923	0.16
Cost of pre-hospital EMS care (£)				
Base-case value + 25%	459	32,444	18,909	0.08
Base-case value − 25%	275	32,392	18,878	−0.08
Cost of post-discharge care (CPC 1 or 2), first year (£)				
Base-case value + 25%	4532	35,974	20,966	10.97
Base-case value − 25%	2719	28,862	16,821	−10.97
Cost of post-discharge care (CPC 3 or 4), first year (£)				
Base-case value + 25%	58,786	35,974	20,966	10.97
Base-case value − 25%	35,272	28,862	16,821	−10.97

TABLE 85 Results of deterministic (one way and multi-way) sensitivity analyses (*continued*)

Parameter	Parameter value	ICER (£ per QALY)	ICER (£ per LYG)	Difference (base : base-case ICER) (%)
Cost of post-discharge care (CPC 1 or 2), subsequent years (£)				
Base-case value	3626	31,253	18,214	−3.59
10% lower than base-case value for CPC1/CPC2, first year	3263	31,253	18,214	−3.59
Cost of post-discharge care (CPC 3 or 4), subsequent years (£)				
Base-case value	47,029	31,253	18,214	−3.59
10% lower than base-case value for CPC3/CPC4, first year	42,326	31,253	18,214	−3.59
Proportion of patient classified as CPC1–4 at hospital discharge				
Alternative values from Andersen *et al.*[126]	CPC1: 0.712 CPC2: 0.159 CPC3: 0.073 CPC4: 0.056	27,134	16,309	−16.30
Alternative values from Phelps *et al.*[129]	CPC1: 0.638 CPC2: 0.177 CPC3: 0.101 CPC4: 0.084	30,024	17,303	−7.39
Time horizon				
Shorter time horizon	5 years	40,913	24,726	26.20
Longer time horizon	20 years	26,013	13,694	−19.76

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TABLE 86 Results of scenario 1: 24/7 coverage, 500 m, accounting for existing AEDs

	Total expected cost (£)	Total expected QALYs	LYG	ICER (additional £ per QALY gained)	ICER (additional £ per LYG)
CP	8925	0.240	0.413		
Public houses, bars and inns	9084	0.244	0.421	35,248	20,543
Post office	9010	0.242	0.418	32,093	18,704
Place of worship	9150	0.246	0.424	35,021	20,410
Chemists and pharmacies	9039	0.243	0.419	32,715	19,067
Dental surgeries	9005	0.242	0.417	32,842	19,141
Doctors' surgeries	9005	0.242	0.417	32,682	19,047
Cash machines	9170	0.247	0.425	34,420	20,060
Banks and building societies	8957	0.241	0.415	34,399	20,048
Nursing and residential care homes	9090	0.245	0.421	33,982	19,805
Halls and community centres	9053	0.243	0.420	33,993	19,811
Gyms, sports halls and leisure centres	9045	0.243	0.419	34,211	19,939
Supermarket chains	8987	0.242	0.416	32,925	19,189
State first, primary and infant schools	9094	0.244	0.421	36,515	21,281
State secondary schools	8957	0.241	0.415	38,096	22,202

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TABLE 87 Results of scenario 2: actual coverage, 100 m, accounting for existing AEDs

	Total expected cost (£)	Total expected QALYs	LYG	ICER (additional £ per QALY gained)	ICER (additional £ per LYG)
Current	8683	0.230	0.397		
Public houses, bars and inns	8716	0.231	0.398	44,385	25,868
Post office	8688	0.231	0.397	45,235	26,363
Place of worship	8705	0.231	0.398	45,367	26,440
Chemists and pharmacies	8694	0.231	0.398	44,341	25,842
Dental surgeries	8688	0.231	0.397	45,283	26,391
Doctors' surgeries	8688	0.231	0.397	45,446	26,486
Cash machines	8752	0.232	0.400	41,904	24,422
Banks and building societies	8688	0.231	0.397	44,539	25,958
Nursing and residential care homes	8747	0.232	0.400	39,645	23,105
Halls and community centres	8705	0.231	0.398	43,383	25,284
Gyms, sports halls and leisure centres	8694	0.231	0.398	44,319	25,829
Supermarket chains	8690	0.231	0.397	43,123	25,132
State first, primary and infant schools	8686	0.230	0.397	47,466	27,664
State secondary schools	8683	0.230	0.397	47,285	27,558

TABLE 88 Results of scenario 3: actual coverage, 1000 m, accounting for existing AEDs

	Total expected cost (£)	Total expected QALYs	LYG	ICER (additional £ per QALY gained)	ICER (additional £ per LYG)
Current	8836	0.236	0.407		
Public houses, bars and inns	8975	0.240	0.413	38,926	22,686
Post office	8861	0.237	0.408	39,010	22,735
Place of worship	8942	0.239	0.412	41,007	23,899
Chemists and pharmacies	8870	0.237	0.409	39,515	23,030
Dental surgeries	8849	0.237	0.408	38,301	22,322
Doctors' surgeries	8851	0.237	0.408	37,776	22,016
Cash machines	9182	0.246	0.425	34,464	20,086
Banks and building societies	8842	0.236	0.408	38,256	22,296
Nursing and residential care homes	9059	0.243	0.419	33,512	19,531
Halls and community centres	9038	0.242	0.418	32,973	19,217
Gyms, sports halls and leisure centres	8930	0.239	0.412	37,258	21,714
Supermarket chains	8891	0.238	0.410	35,824	20,878
State first, primary and infant schools	8855	0.237	0.408	41,462	24,164
State secondary schools	8840	0.236	0.407	42,528	24,785

TABLE 89 Individual and population EVPI

Ceiling ratio	Individual (£)	Expected population (Over 10 years) (£)	(Over 5 years) (£)
£0 per QALY	0	0	0
£30,000 per QALY	8	2,269,593	1,232,153
£80,000 per QALY	0	3155	1713

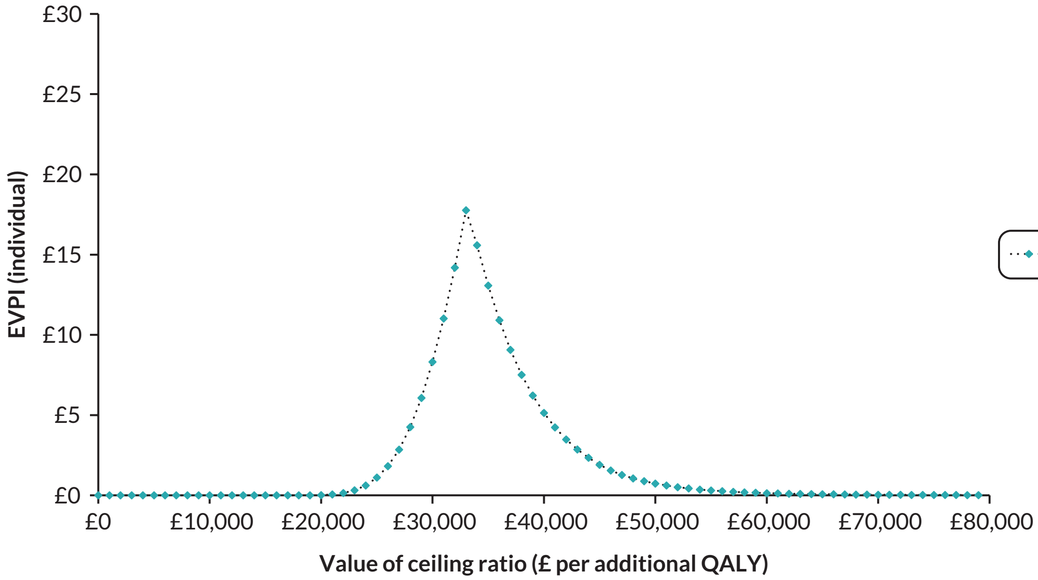

FIGURE 34 Individual-patient EVPI for halls and community centres: different values of the ceiling ratio.

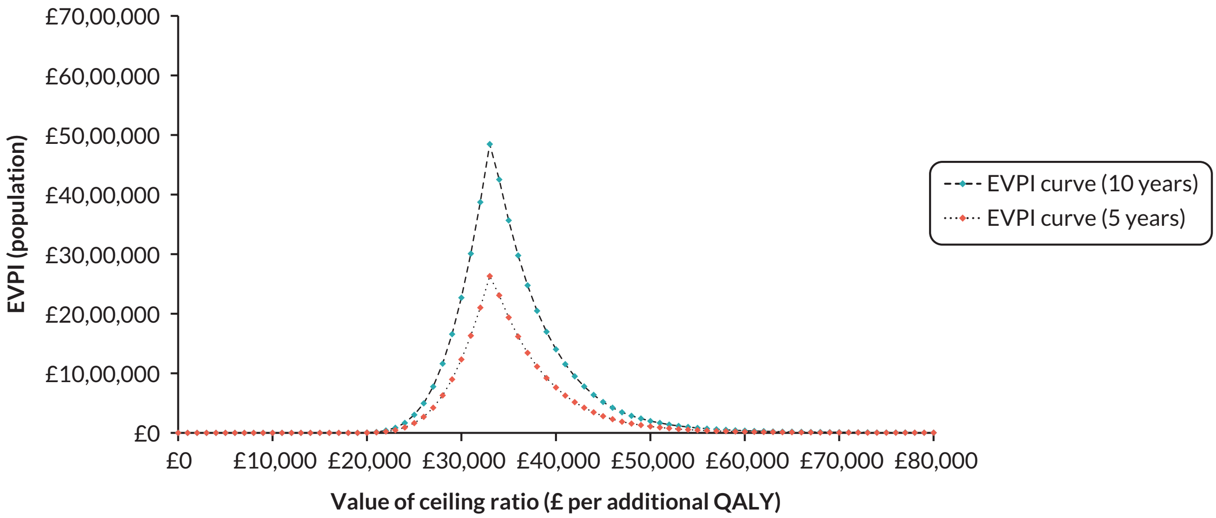

FIGURE 35 Population EVPI for halls and community centres: different values of the ceiling ratio and for different assumptions of the time before decision is superseded.

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