PAD-Op

RESEARCH PROTOCOL

Optimisation of the Deployment of Automatic External Defibrillators in Public Places in England (PAD-Op)

Sponsor:	University Hospitals Birmingham NHS Foundation Trust/University of Warwick
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1 LAY SUMMARY

Background: NHS Ambulance Services treat around 30,000 people whose hearts suddenly stop each year. This is a condition known as cardiac arrest. Despite ambulance services best efforts less than one in ten (10%) survive. Electric shock treatment, known as defibrillation, is one of the most effective treatments. If an electric shock is given within a few minutes of the heart stopping, over half the people treated (50%) survive. The more time that passes before the electric shock is given the less effective it is. It takes an ambulance on average 8 minutes to get to someone whose heart has stopped. This is too late in many cases to save the patient's life. It is now possible for members of the public to use an automatic machine (defibrillator) to safely give an electric shock to the heart. In order for the public to make best use of these machines, they need to be in the right places.

Aim: This project will work out where the best places are to put electric shock machines (defibrillators) in our communities. This will make them more accessible and should save more lives.

Design and Methods: We have collected information about where people have a cardiac arrest over the course of the last five years. This is a good marker for where people will have cardiac arrests in future years. We will compare where cardiac arrests occurred with locations of the defibrillators. From this we can work out how much of the country is covered by defibrillators. We will see if there are better ways of deciding where to put the defibrillators. For example they could be placed according to:

- Particular building types (e.g. schools, coffee shops);
- Places where lots of people go (e.g. shopping centres, railway stations);
- Divide the country up into small squares with a defibrillator placed in each square; or
- Use a computer to model the best locations.

There is a limited amount of money that the country spends on defibrillators each year (it was £2-5 million a year for the last 2 years). We will work out which of these ways will save most lives and give the best value for money.

Patient and Public Involvement: We have worked closely with members of the public to develop this project, and will work closely with patients and the public, and charitable organisations, to ensure that their views are fully included in the project. We are very fortunate that a member of that group, who has personal experience of losing someone in the circumstances described here, has agreed to join our research team. He has worked with other patients over the year to help improve research in this area. He will work with our research team and a group of patients and members of the public to guide the research team to remain focused on the issues that are important to patients. His group will be involved in helping design, interpret and communicate the research. They will play an important role in developing the final recommendations.

Dissemination: Our team has experience of working with key people and organisations interested in improving survival from cardiac arrest. We will summarise the findings of this project in talks and written reports. We will work with key organisations who are responsible for deciding where defibrillators are placed in the community. This includes charities such as the British Heart Foundation, Community Heartbeat Trust, HeartSafe, Arrhythmia Alliance, etc. We will also talk to Ambulance Services and those who organise healthcare (NHS England). We will work with our press and communications team to share with the wider community through press releases and use of social media. This will help ensure the findings of the project are put to good use.

2 STUDY SUMMARY

Study Title	*Optimisation of the Deployment of Automatic External Defibrillators in Public Places in England*
Internal ref. number (or short title)	*PAD-Op*
Study Design	*Study is a secondary statistical analysis of anonymised data collected by the Out-of-Hospital Cardiac Arrest Outcomes (OHCAO) registry. The project consists of four work packages with the following objectives:* *1. Explore the characteristics of current locations of AEDs and determine the proportion of OHCAs that occur within specified distances;* *2. Compare the coverage of various AED deployment strategies and an optimisation model with the current coverage;* *3. Determine the cost-effectiveness of implementing the optimised placement strategy compared to current placement;* *4. Develop a national consensus of the optimal location for public-access AEDs*
Study Participants	*The OHCAO registry collects details of all patients that suffer an out-of-hospital cardiac arrest, and where resuscitation is continued or commenced by emergency medical staff. Anonymised details of these cases will be provided to the project.*
Planned sample size	*The OHCAO registry will contain details of up to 200,000 OHCA patients by the end of 2019*
Planned study period	*Study start: 1st October 2019* *Study end: 30th June 2022*

3 LIST OF ABBREVIATIONS/GLOSSARY

Abbreviation	Explanation
AED	Automatic External Defibrillator
CI	Chief Investigator
CPR	Cardiopulmonary Resuscitation
CTU	Clinical Trials Unit
DMC	Data Monitoring Committee
DNACPR	Do Not Attempt Cardiopulmonary Resuscitation
GCP	Good Clinical Practice
GDPR	General Data Protection Regulations
IRAS	Integrated Research Application System
JRCALC	Joint Royal College Ambulance Liaison Committee
MRC	Medical Research Council
OHCA	Out-of-Hospital Cardiac Arrest
OHCAO	Out-of-Hospital Cardiac Arrest Outcomes
PAD	Public Access Defibrillator
PI	Principal Investigator
PPI	Patient & Public Involvement
REC	Research Ethics Committee
R&D	Research and Development
ROLE	Recognition of Life Extinct
ROSC	Return of Spontaneous Circulation
SOP	Standard Operating Procedure
TSC	Trial Steering Committee
WCTU	Warwick Clinical Trials Unit
WP	Work Package

4 BACKGROUND

4.1 EPIDEMIOLOGY AND BURDEN OF THE CARDIAC ARREST

English NHS ambulance services treat approximately 30,000 out-of-hospital cardiac arrest (OHCA) cases annually; about 22% of which achieve a return of spontaneous circulation (ROSC) by the time of hospital handover and 7-8% survive to hospital discharge [1]. There is also e evidence of significant regional variation in the incidence across England [2]. Any delay between collapse and treatment of OHCA decreases the probability of survival significantly [3]. The chain of survival show the essential elements required in an emergency care system to improve outcomes from OHCA. The first two links – early recognition and early cardiopulmonary resuscitation – can but time for the OHCA patient but are not definitive treatments in themselves. The key and most effective treatment for cardiac arrest is defibrillation.

Figure 1: Chain of survival

4.2 EXISTING KNOWLEDGE

Ventricular fibrillation (VF) or ventricular tachycardia (VT) are the most common causes of sudden OHCA. Prompt treatment of VF/VT with a defibrillator, within 3-5 minutes of collapse, can lead to survival rates in excess of 50% [4-7]. 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 unresponsiveness to treatment. The quality of life of OHCA survivors in general is good [8,9], while bystander defibrillation decreases the risk of brain damage and nursing home admission even further [10].

Public access defibrillation (PAD) describes the use of automatic external defibrillators (AED) 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 is making reaching OHCAs in a timely manner challenging. However, at present, only a small proportion of UK patients are treated by PAD (2.4%) [1] with average timing of use from OHCA often exceeding 4 minutes [11] leaving a large number of patients who fail to benefit from PAD.

Figure 2: Barriers to bystander defibrillation – key themes

A fundamental, structural barrier, which limits opportunity for the use of AEDs, is their location in the community. The further away a patient is from an AED the less likely it will be used [12]. 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. 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 [13,14]. Therefore, 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.

Any delay between collapse and treatment of OHCA decreases the probability of survival significantly [3]. A greater proportion of OHCA cases may have a shockable rhythm (VF or VT) at the time of collapse, as high as 76% [5,15]. However, by the time the rhythm is assessed, it may have deteriorated to asystole [16,17]. Interventions by the public, including using an AED, doubles the chance of survival with favourable neurological outcomes [18,19] and reduces hospital resource utilisation [20-23]. 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 patient. This implies that survival and therefore the "coverage" of an OHCA by a defibrillation device decreases as a function of distance [3,24-26]. Each minute of delay of defibrillation reduces the probability of survival to discharge by 10% [25].

The benefits of using public-access AEDs and PAD are irrefutable. When an OHCA patient receives bystander cardiopulmonary resuscitation (CPR) and has an AED applied the survival rate was 24%, compared to when no AED was applied (7%) [15]. If the AED gave a shock (i.e. the patient was in VF/VT) when applied, the survival rate was even higher (38%). AED application was associated with greater likelihood of survival. More recently, the evidence indicates that patients shocked by a bystander were significantly more likely to survive to discharge and be discharged with favourable neurological outcome than patients initially shocked by EMS [27]; and that the benefit of bystander shock increased as EMS response time became longer.

Nevertheless, AEDs are only cost-effective when located in places where the probability of their use is high, i.e. they are not inside a building, in an accessible cabinet, available 24-hours 7-days a week [23,28]. There is a notably poor correlation reported between OHCA location and location of AEDs [29,30], and that 1 in 5 OHCAs

occurred near an inaccessible AED at the time of the OHCA [31]. Also, in only a minority of OHCA cases (about 7%) was an AED location within 100m [32]. Recent studies have also observed significantly fewer AEDs were present in residential areas of urban settings and the median distance between OHCA location and the AED was larger here than in non-residential areas [33]. 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.

There is sufficient evidence to recommend AED placement in specific locations wherever large numbers of people congregate, where there is a high OHCA risk, like bus/railway stations, airports, convention centres, sports stadiums and arenas [13,34-39], but not in other public sites. 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 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 OHCAO registry has shown [2]. These include the level of deprivation in the area, the proportion of people in the area from different ethnic groups and countries outside UK, the proportion of people in different social classes and higher educational qualifications. Rural areas also pose significant optimisation issues due to geographical challenges to cover villages; the distance between rural OHCAs and AEDs are significantly greater than in urban areas [40].

Although millions are spent annually in the deployment of AEDs and training of individuals in their use, the impact is currently limited, given the extremely low utilisation rates during actual OHCA [1]. Optimisation of the location of public-access AEDs will result in improved access to them, increase the proportion of OHCA patients who receive early defibrillation, and consequently result in an increased return on this societal investment.

PAD programmes that deploy AEDs are feasible, and their use by lay persons has proved an effective strategy in the management of OHCA. A previous (1999-2005) 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 return of spontaneous circulation was achieved in 39% of patients and survival in 26% [41]; compared to the latest figures for England of 25.8% and 7%, respectively [1]. Despite several campaigns to raise public awareness and make PAD more available, many public areas have no recorded AED available [42].

AED 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% [43]. Recent work in UK has shown that the availability of AEDs at night was only 34.3%, and existing AEDs were significantly underused; 36.4% of OHCAs are located within 500m of an AED [40]; also about 6% of OHCAs were within a retrieval (walking) radius of 100m 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 survival after OHCA.

There is much debate about where AEDs should be placed, namely 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 a large amount may be very costly if not managed properly and preceded by public awareness [13,44-47]. Instead, target AED placement matching known country and region-specific OHCA event rates in addition to efforts of improving accessibility of existing AED units is likely to be most cost effective [15,48-51]. Furthermore, different approaches may be needed for public versus private coverage and metropolitan versus rural area coverage.

The International Liaison Committee on Resuscitation indicate that there are substantial knowledge gaps about optimal AED deployment strategies, stressing the need for scientific evidence to support these [14]. The density and location of AEDs required for a sufficiently rapid response is not well established, especially

when cost-effectiveness is a consideration. According to the European Resuscitation Council (ERC) the effective use of an AED in the event of an OHCA requires that an AED is near the OHCA location, the ambulance service know the location of AEDs in the proximity of the OHCA, that lay responders are made aware of the AED location and are willing/able to retrieve and use the AED. Guidelines also 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 100m^2) and the time to defibrillation following collapse (3-5 minutes) [16,28,52]. Anticipated OHCA frequency is based on evidence from North America that indicated OHCAs are more likely to occur in neighbourhoods with certain characteristics [53-55], and our analysis of data from the OHCAO registry [2], e.g. those with greater proportion of ethnic minorities, lower income (greater number living in poverty), low levels of education, a greater level of deprivation, and areas with an older population. This evidence is continually being updated in UK as part of the work programme of the 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 publically accessible AED, in any given community is not clear, although a significant amount of work has been carried out in other countries [31,34,56-58]. Recently, data from the OHCAO registry has been able to identify the characteristics of neighbourhoods where OHCA incidence is high as indicated earlier [2]. These neighbourhoods were also classified as 'high risk', where in addition to a high OHCA incidence the bystander CPR was also low.

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 cardiac arrest risk. Therefore, it is of essence to determine a relevant subset of locations for AED placement that have the 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; placement being primarily in affluent areas with low OHCA incidence [13,34]. This risks increasing health inequalities. AED deployment strategies must switch from subjective and opinion-based towards objective and evidence-based criteria that will make it possible to identify the optimal number of and best location for outdoor AEDs.

4.3 RESEARCH QUESTION

In cases of OHCA 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.

4.4 NEED FOR A STUDY

4.4.1 Health need

In OHCA patients, prompt bystander interventions, including PAD, significantly reduces hospital length of stay and ICU admission; improves the likelihood they will survive; decreases their risk of brain damage and chance they are nursing home dependent [10,20]. Increasing the availability to an AED increases the likelihood they will used, but this is dependent on them being placed in an optimal location so that they could be retrieved promptly to treat an OHCA.

4.4.2 Expressed need

This proposal is highly relevant to the needs of patients who suffer an OHCA. This is articulated through:

- Department of Health Cardiovascular Outcome Strategy and NHS England's Resuscitation to Recovery strategy place a high priority on improving survival from OHCA though better use of PAD [59];
- Department of Health investment of £1 million each year to place AEDs in the community;
- Large geographical variation in survival from OHCA versus the drive to reduce variation in the NHS as a whole, and specifically within ambulance services;
- The need to optimise emergency care pathways (chain of survival) to improve patient outcomes and reduce waste through safe, effective care;
- British Heart Foundation and Resuscitation Council (UK) commitment to increasing the rate of use of public access-AEDs by a bystander, by improving awareness, availability and visibility of public access-AEDs;
- NHS commitment to ensure that public funds are spent prudently, through approaches that are shown to represent 'value for money';
- NHS duty to reducing health inequalities in the Health and Social Care Act (2012), Equality Act (2010) and Social Value Act (2012).

4.4.3 Sustained interest and intent

As the number of OHCAs is increasingly annually, and demand on acute services continues to grow, the results of this research will remain highly relevant and important to the needs of the NHS in the future.

4.4.4 New knowledge

The evidence, which has created the knowledge about optimising the placement of public-access AEDs, is derived mainly from North America [31,34,56,57]. However, the models developed cannot be applied directly to UK because approaches to health service financing and delivery, urban design elements, climate, geography and other factors differ markedly. In addition, the models that have been developed focus on urban areas. This creates the specific need to generate new knowledge generalizable to the UK.

4.4.5 Generalisability and prospects for change

This work will draw on Ambulance Service data to quantify and model the effect of new approaches to the placement of AEDs in public places. The study team are members of NHS England Community Resuscitation Group, Resuscitation Council (UK) Community and Ambulance Resuscitation Committee, and National Ambulance Research Steering Group and, therefore are ideally place to influence change in the current, ad hoc approach to one built on evidence.

4.4.6 Building on existing work

The group has a strong track record of high quality research in OHCA (e.g. HTA Paramedic 1&2, HSDR regional variation in OHCA) which has had a significant impact on NHS and international policies. This study builds directly on work that identified significant inequalities in the neighbourhood characteristics of areas where OHCAs are more likely to occur and be witnessed, but where bystander CPR is less likely to occur [2], and that identified significantly low usage of PAD [1]. It dovetails with the NIHR TCC funded project on GoodSAM.

The project will make use of the national OHCAO registry, established in 2013 and hosted by the University of Warwick improving efficiency and reducing costs. The registry receives information on the epidemiology and outcome of OHCAs across England. Data from ambulance service is collected according to the international Utstein definitions [60]. The registry has Research Ethics Committee (13/SC/0361) and Confidentiality Advisory Group (ECC 8.04(C)/2013) approval to use identifiable patient information where it is not practical to obtain consent.

5 STUDY DESIGN, CONSIDERATIONS AND PROCEDURES

5.1 STUDY SUMMARY AND FLOW DIAGRAM

This is a study that performs a secondary analysis of anonymised prospective observational data. The data consists details of all out-of-hospital cardiac arrests where ambulance staff continue or commence resuscitation, and is provided by UK NHS Ambulance Services. The data will be shared by the OHCAO project that is based within the Clinical Trials Unit at the University of Warwick, in which both Cis play a leading role.

This section presents an overview of the study, its ethical considerations and procedures across the four work packagers (WPs). Details of the individual WPs are in sections 6 (WP1), 7 (WP2), 8 (WP3) and 9 (WP4).

5.1.1 Primary objective

The study consists of four WPs. The primary aim of the study is to develop a model that would 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 PAD, improving their chances of survival. To assess the cost-effectiveness of optimised public-access AED placement compared to current placement.

5.1.2 Secondary objective

To meet the primary aim we plan to achieve the following objectives, which also shown in figure 3:

- Determine the current coverage of known public-access AEDs to be used to treat historical OHCAs;
- Model the characteristics of different deployment strategies for public-access AEDs;
- Develop a mathematical optimisation model for AED deployment, accounting for spatial and temporal accessibility;
- Determine the costs and benefits associated with the placement strategies developed and compare these against current practice.
- Develop a national consensus of the optimal location for public-access AEDs.

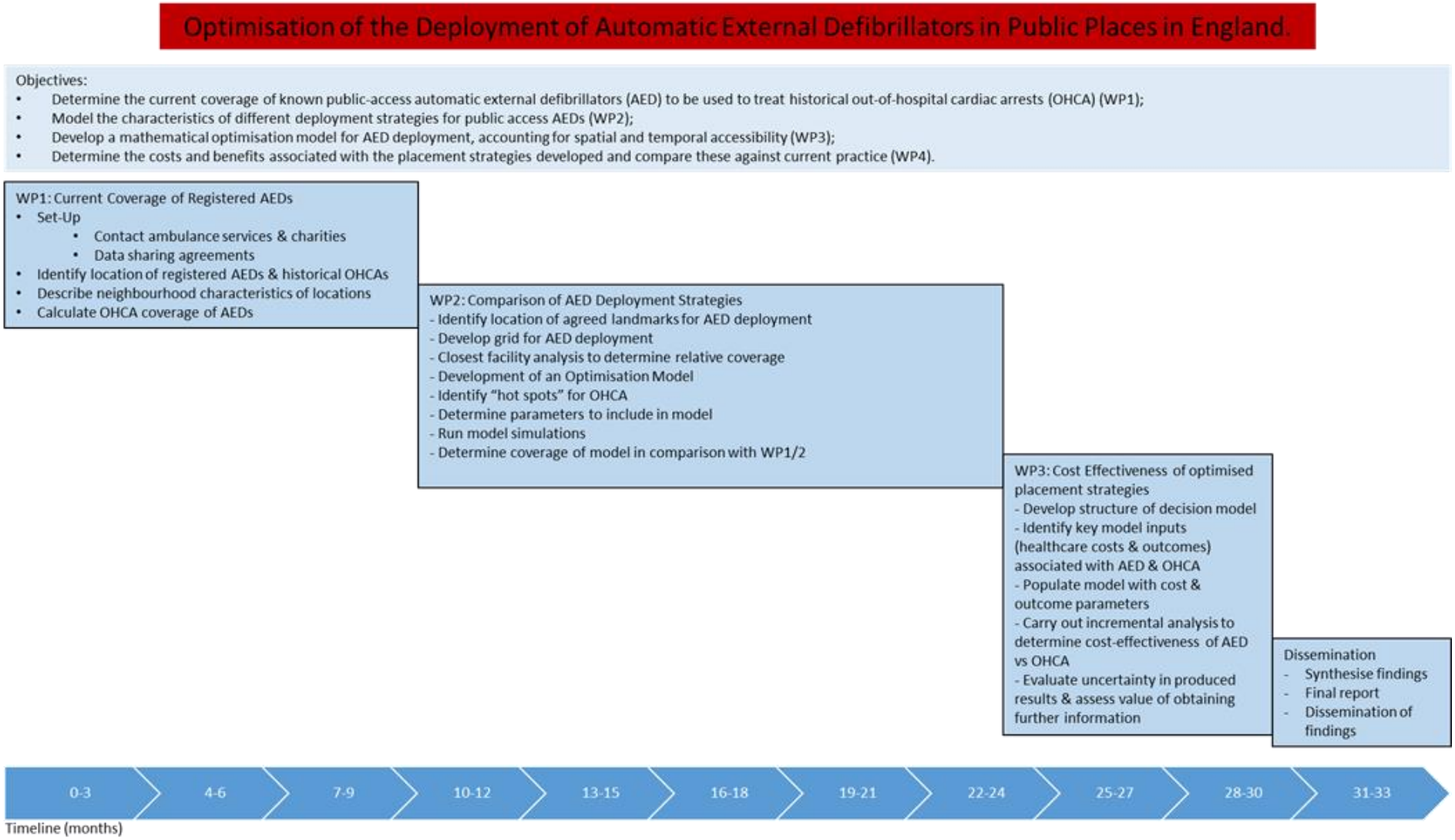

Figure 3: PAD optimisation study flow diagram

5.2 RECRUITMENT SUMMARY

Anonymised information on patients with out-of-hospital cardiac arrest will be obtained from the OHCAO registry during WP1. Patients are eligible to be included in the registry if they meet the following criteria:

5.2.1 Inclusion criteria

1. Patients of all ages/sex who suffer a documented out-of-hospital cardiac arrest.
2. Resuscitation is attempted (Advanced or Basic Life Support) commenced/continued by ambulance service.

5.2.2 Exclusion criteria

1. Patients have a Do Not Attempt Cardiopulmonary Resuscitation (DNACPR) order in place.
2. Arrest during inter-hospital transfer or on acute NHS hospital trust premises
3. Patients with clear evidence of death defined by the Joint Royal College Ambulance Liaison Committee (JRCALC) Recognition of Life Extinct (ROLE) criteria.
4. Bystander suspected an OHCA where the patient is not in cardiac arrest on arrival of EMS, or no defibrillation prior to arrival, or no evidence verifying an OHCA state is present.
5. Patients that achieve ROSC prior to the arrival of EMS unless they subsequently re-arrest in the presence of paramedics.

5.3 SITE STAFF TRAINING

The study is based solely at University of Warwick. Training in geographical information systems is being sought.

5.4 ETHICAL CONSIDERATIONS

The study will be conducted in full conformance with the principles of the Declaration of Helsinki and to Good Clinical Practice (GCP) guidelines. It will also comply with all applicable UK legislation and Warwick Standard Operating Procedures (SOPs). All data will be stored securely and held in accordance with Data Protection Act 2018.

We will seek University of Warwick Biomedical and Scientific Research Ethics Committee (BSREC) approval early in the study. There are no ethical concerns in the project because all the data will be anonymised. Anonymous information will be sent securely from the OHCAO team under the terms and conditions of a data sharing agreement. OHCAO hold this information with permission from Research Ethics Committee (REC) reference 13/SC/0361, and Confidentiality Advisory Group (CAG) approval reference ECC 8-04 C/2013.

5.5 DATA COLLECTION

5.5.1 OHCA Information

Details of all OHCAs that have occurred in England between 1st January 2014 and 31st December 2019 will be obtained from the OHCAO registry following the approval of a data sharing agreement (DSA). A formal DSA application procedure has been established by the OHCAO project and this will be followed. Variables to be obtained are detailed in section 6.2.

5.5.2 AED Information

Details of the location and availability of AEDs in England will be obtained from the Ambulance services and the various charities that run AED programmes. Formal DSAs will be put in place for them to provide the required information (section 6.1).

5.6 DATA MANAGEMENT

All data collected during the study **does not** contain personal identifiable information. All data collected during the study will be handled and stored in accordance with the 1998 Data Protection Act and 2018 General Data Protection Regulation.

5.6.1 Data collection and management

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

5.6.2 Database

No formal databases will be required for this study.

5.6.3 Data storage

All essential documentation and study records will be stored by WCTU in conformance with the applicable regulatory requirements and access to stored information will be restricted to authorised personnel. Any paper forms, meeting notes or other documents will be stored in a lockable filing cabinet in a secure room, to which access is restricted to authorised personnel. Electronic data will be stored in a secure area of the computer with access restricted to staff working on the study.

5.6.4 Data access and quality assurance

No personal identifiable information is being collected by this study. Each record will be assigned a unique study identifier that is linked to the OHCAO registry information for the purposes of audit/quality assurance. This linkage will only be known to the OHCAO research team.

Once the study has been completed the records will be destroyed according to WCTU SOPs. The CI will have access to the final study data set from all four work packages. Access requests from both co-investigators and external parties will be considered by the CIs. A formal process will be developed by the study team to facilitate such requests and decisions. Any data shared will be anonymised and transferred as per WCTU SOPs with data sharing agreements in place.

5.6.5 Data Shared with Third Parties

OHCA and AED location data will be shared with colleagues at the University of Toronto to enable them to run their previously developed optimisation model. A formal data sharing agreement will be put in place that will enable them to access the required information remotely.

5.6.6 Archiving

Study documentation and data will be archived for at least ten years after completion of the study at WCTU.

5.6.7 End of study

The study will officially end on the last day of funding, 30th June 2022, although dissemination of results will continue beyond that date.

Since the study is not implementing any intervention, it is unlikely to be stopper prematurely, unless funding is ended early.

The Research Ethics Committee will be notified in writing within 90 days when the study has been concluded or within 15 days if terminated early.

6 CURRENT COVERAGE OF REGISTERED AEDS (WP1)

6.1 AIM

To explore the characteristics of current locations of AEDs relative to the location of cardiac arrests

6.2 OBJECTIVES

- Identify the location of all registered AEDs and historical out of hospital cardiac arrests in England
- To describe the neighbourhood characteristics of locations of registered AEDs
- To determine out of hospital cardiac arrest coverage of registered AEDs

6.3 WP1.1 AED INFORMATION:

We will obtain a list of registered public-access AEDs in England from each ambulance service, which will be cross-referenced with databases held by charities.

No personal information will be collected as part of work. Information to be obtained will include:

- Location of AED (address, postcode, inside/outside building if at specific address)
- Registered with ambulance service
- Availability (hours in the day, days of week)

A formal data sharing agreement (DSA) will be established with each organisation that agrees to participate.

WP1.2 Out of hospital cardiac arrest information

We will conduct a retrospective observational study of ambulance-attended out of hospital cardiac arrests, of all ages, where resuscitation is continued or commenced by any of the services. We will consider all out of hospital cardiac arrest episodes between 1st January 2014 and 31st December 2019, regardless of initial out of hospital cardiac arrest rhythm or presumed cause. We will exclude those episodes where it is not possible to determine, with certainty, the exact out of hospital cardiac arrest location. Each year the OHCAO registry receives details of about 30,000 OHCA cases. By the end of 2019 the registry will contain details of about 200,000 OHCAs. Based on previous analyses 2 approximately 85% of these cases will have sufficient information to allow for the analysis to develop the optimisation model and undertake the cost-effectiveness analysis. The sample of 170,000 is deemed sufficient to develop the model. Previous studies have used significantly smaller samples to develop their models [56-58,61,62].

The data will be obtained from the Out-of-Hospital Cardiac Arrest Outcomes (OHCAO) registry which is hosted by at the University of Warwick. The registry is structured and maintained in accordance with the Utstein guideline for resuscitation registries[63]. Full details of the registry can be found elsewhere[64], or the internet. (https://warwick.ac.uk/fac/sci/med/research/ctu/trials/ohcao).

The National Research Ethics Service granted ethics approval, reference number 13/SC/036. The Confidential Advisory Group, reference number ECC8-04(C)/2013, granted approval to use identifiable patient information where it is not practical to obtain consent. As members of the research team form part of the OHCAO registry team no formal data sharing agreement, or further ethical or CAG approval are required to obtain the data required. As the co-applicants work on the OHCAO project no formal data sharing agreement will be required to obtain this information.

Data will be anonymised. Data required will include:

- Time of out-of-hospital cardiac arrest

- Location of out of hospital cardiac arrest (geographic coordinates, e.g. easting/northing)
- Age/Sex
- Whether the out of hospital cardiac arrest was witnessed or not
- Whether bystander CPR was administered
- Availability and use of public access defibrillator
- Ambulance response time, calculated from the difference between "Clock start" and "Clock stop" recorded in accordance with NHS England standards.

6.3.1 Proof of concept

In response to the panels request for reassurances about the feasibility of data linkage, we undertook a small proof of concept study using data from the West Midlands. This demonstrates the feasibility of mapping cardiac arrest locations, AED locations supplied by Ambulance Services and landmarks (in this example schools) as illustrated in table below[65]. The study showed that 3.7% of out of hospital cardiac arrests occurred within 100m of a school, and 8.4% within 100m of an existing AED. Approximately 37% of out of hospital cardiac arrests occurred within 300m of a school or existing AED.

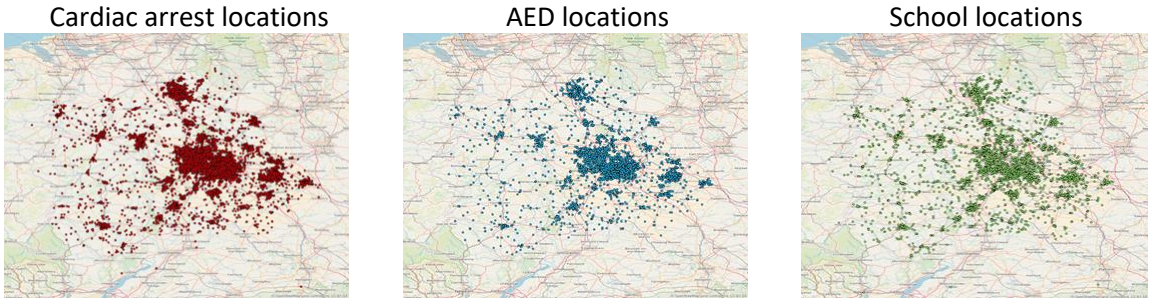

Figure 4: OHCA, AED and school locations in West Midlands

6.4 WP1.3 Neighbourhood Characteristics

We have previously shown there is variation in access to bystander CPR according to neighbourhood characteristics[2]. Characteristics associated with low bystander CPR were high levels of deprivation; high population density; and low proportion of population of white ethnicity, lower occupations, proportion aged >65 years, and proportion born outside the EU. Similarly, the incidence of OHCA was also been shown to vary according to these characteristics. Therefore, we can assume that the risk of cardiac arrest and bystander CPR intervention is homogenous around each location.

We will describe the neighbourhood characteristics and locations where out of hospital cardiac arrests have occurred and public-access AEDs are positioned. Middle layer super output area (MSOA) will be used as the proxy unit of neighbourhood to describe these characteristics. Output areas are used by the Census and built from clusters of adjacent unit postcodes and are designed to have similar population sizes and be as socially homogenous as possible based on household tenure and dwelling type. There are 7201 MSOAs in England with a population range of 5000-15000, and household number of 2000-6000. The geographic location (from WP1.4) will be converted to the corresponding MSOA using data from https://data.gov.uk/ website. Neighbourhood characteristics, freely available from the Office for National statistics via the https://nomisweb.co.uk website, to be considered will include:

- Residential population density
- Workday population density
- Proportion of people living alone
- Proportion of people from different ethnic groups (white, mixed, non-white)
- Proportion of people with high education (A-level and higher)
- Proportion of people living with a long-term health problem or disability

- Proportion of people in different socio-economic groups based on occupation
- Proportion of people aged <65y and over65y Index of multiple deprivation

In addition the Index of Multiple Deprivation and Rural Urban classification for each MSOA will be obtained from the https://www.gov.uk website.

6.5 WP1.4 Analysis

Descriptive statistics will be used to analyse for any differences in neighbourhood characteristics (t-test, chi-square). We will carry out sensitivity analyses that take into account potential future changes in the neighbourhood characteristics and their potential impact on OHCA incidence. In addition, we will carry out a Bayesian analysis of OHCA risk, where the risk in adjoining areas might influence the risk in the area of concern.

Geographic data for all registered AEDs and historical out of hospital cardiac arrests will be converted (geocoded) into the easting/northing format that will allow for the mapping of AED and OHCA locations and calculation of distance between two points. For locations containing multiple AEDs, we will attempt to determine the exact easting/northing. We will plot all data points in ArcGIS (Esri). ArcGIS is a geographic information system for working with maps and geographic information and used to create and using maps, compiling geographic data and analysing mapped information. The walking distance from each out of hospital cardiac arrest location to the closest current AED location will be calculated. The analysis will be split into two parts: (i) those out of hospital cardiac arrests known to have occurred in public places, and (ii) the whole dataset of out of hospital cardiac arrests.

We will estimate the number of historical out of hospital cardiac arrests that were covered based on two definitions. Firstly, we will calculate 'assumed 24/7 coverage', where an out of hospital cardiac arrest is considered covered if it occurred within 100m of any AED. The 100m coverage radius is selected as an approximation of the maximum round-trip distance a bystander could travel to retrieve and set-up an AED within 3 minutes[56,66,67]. Secondly, we will calculate 'actual coverage', where an out of hospital cardiac arrest is considered covered if it occurred within 100m of an AED and when the AED was available at the time of the out of hospital cardiac arrests. AEDs will be classified as 24/7 available (e.g. cabinet on an external building of a wall or known 24/7 facility), or daytime-only availability (assumed to be approximately 08:00-18:00) if they were located in what can be termed a static state (e.g. doctor's surgery, shopping centre and commercial building).

Using the coverage definition, we will then calculate the 'coverage loss', which is defined as 'assumed 24/7 coverage' minus 'actual coverage', and then divided by 'assumed 24/7 coverage'. Coverage loss will be examined for different times of the day (daytime: 08:00-15:59; evening: 16:00-23:59; night: 00:00-07:59), days of the week, (weekday and weekend), geographic area (cities, towns, rural) and by location type where registered AEDs are placed. Sensitivity analysis will be carried out using a range of distances (e.g. 150m, 200m). We will also consider the impact of neighbourhood characteristics described above, as well as average ambulance response times in each MSOA. The 95% confidence intervals (CI) will be calculated for the coverage loss using an error propagation and paired proportions approach to change absolute to coverage loss CIs. To test for statistical significance in coverage loss across disjoint and unpaired categories (time of day, day of week, and geography), a chi-squared test will be used.

Output: Report summarising the current locations of PAD, their relationship with neighbourhood characteristics and proportion out of hospital cardiac arrest that occur within specific distances.

7 COMPARISON OF AED DEPLOYMENT STRATEGIES (WP2)

7.1 AIM

To compare the coverage of various AED deployment strategies and an optimisation model with the current coverage.

7.2 OBJECTIVES

- To assess the coverage of historical out of hospital cardiac arrests using various landmarks/buildings as potential locations for AEDs
- To assess the coverage of historical out of hospital cardiac arrests using a grid as potential locations for AEDs
- To develop a mathematical model that will optimise the deployment of AEDs to enable the greatest coverage of historical out of hospital cardiac arrests
- To compare the coverage of the different strategies and optimisation model with current practice

7.3 WP2.1 DEPLOYMENT STRATEGIES:

Landmark Strategy: We will obtain locations of a list of specific building types (e.g. coffee shops, libraries, schools, public houses, banks, pharmacies), or places where lots of people go (e.g. supermarkets, train stations) and assume that an AED is positioned at the entrance of each one. Location data will be obtained from local business directories, for which there may be a small fee. The Local Data Company (www.localdatacompany.com) are one source that have already been contacted to obtain this information and get an estimate of the cost involved; and they are also able to provide information on footfall by counting the number of mobile phones passing SmartStreetSensors at any given time. Other sources include the Ordnance Survey, and the https://www.gov.uk, Geolytix (https://geolytix.net), EduBase, British Library and Consumer Data Research Centre (www.cdrc.ac.uk) websites.

Grid-Based Strategy: We will divide the country up into 0.25km^2 squares and assume that a defibrillator is placed in the centre of each square. There will obviously be certain grid squares in which placement of an AED is not possible, due to geography and other factors, which will be taken into account.

For each strategy we will assume that existing registered AEDs cannot be moved. We will also carry out a sensitivity analysis that considers a proportion of these can be moved. In the landmark strategy we will also a further sensitivity analysis that considers some of the locations may close down and others open, over the lifetime of the project.

A distance matrix between out of hospital cardiac arrests location and the closest AED will be calculated using ArcGIS “Closest Facility Analysis” tool which uses Dijkstra’s algorithm for finding the shortest path between two points. Sensitivity analyses will be carried out by setting parameters (impedances) that take into account when an out of hospital cardiac arrest occurred (to account for AED availability), distance required to travelled or reached within specified time. Results of median distance and number of AEDs will be reported in plot diagrams. Modelling the distribution of these plots in a nonlinear regression model will create power regression trend lines, the inflection points of which will estimate an optimal number of AEDs to be deployed. We will also consider if an out of hospital cardiac arrests occurred in public versus private locations.

We will compare the coverage of these strategies with that of the current situation using the methodology described in work package 1.

7.4 WP2.2 Optimisation Model:

We will update a spatiotemporal optimisation, which accounts for both spatial and temporal information of out of hospital cardiac arrest events and candidate AED locations, to choose the optimal locations to place AEDs and maximise out of hospital cardiac arrest coverage based on historical out of hospital cardiac arrest incidence. The model has been developed by co-applicants / collaborators in Toronto, Canada[31,56,57,68] and tested in the Netherlands[61] and Copenhagen[62]. The current model is based on a previously validated one for facility location (maximal covering location problem)[69]. The spatiotemporal model will have the following inputs:

1. Addresses and hours of operation of registered AED locations (WP1);
2. Locations and times of historical out of hospital cardiac arrests (WP2);
3. Addresses and hours of operation of candidate AED locations (landmarks or grid-based) (WP2.1); and
4. User-specified parameter *N*, which determines the number of candidate locations where AEDs are to be placed.

The model outputs the number of selected locations that will maximise the actual coverage of historical out of hospital cardiac arrests, as well as the total number of out of hospital cardiac arrests covered.

We will also incorporate ambulance response time into the models recorded in accordance with NHS England standards, and consider developing separate models for urban and rural environments.

The spatiotemporal optimisation model will be compared with a spatial-only optimisation model, the latter does not consider when the out of hospital cardiac arrest occurred or the hours of operation of the candidate AED locations. The two models will be evaluated on the improvement in actual coverage on top of the baseline coverage provided by existing registered AEDs (WP1 and model input #1) of historical out of hospital cardiac arrests in England. To ensure the comparison of the two models is based on external data, we will use a 'k'-fold cross validation approach where the out of hospital cardiac arrests not covered by the existing registered AEDs are randomly partitioned into k equal-sized subsamples (size of 'k' will depend on total number of out of hospital cardiac arrests, but will be minimum of 10) of approximately equal size. One set will be used as a training set while the remaining 'k-1' sets are used as the validating set.

For each fold, the optimisation models will use the validation sets as the historical out of hospital cardiac arrests data (model input #2) to select the optimal AED locations from the candidate AED locations (model input #3). The optimal locations determined by the spatiotemporal and spatial-only models will then be evaluated on actual coverage using that fold's validation set. This process will be carried out for all 'k' folds, producing actual coverage values for each of the 'k' training sets. The models will be run for range of values of *N* (model input #4), depending on the total number of candidate locations. The models will also consider neighbourhood characteristics and average ambulance response times.

The coverage gain for each N is defined as the actual coverage from the spatiotemporal model minus actual coverage from the spatial-only model, divided by actual coverage from the spatial-only model. The overall coverage gain is then calculated by taking the weighted mean of the coverage gain for each *N* (number of locations), weighted by the actual coverage values from the spatial-only model. The 95% confidence intervals (CI) will be computed for the overall coverage gain, as well as for the coverage gain broken down by time of day, day of week, and geography. The out of hospital cardiac arrests coverage of the strategies will be tested against each other by applying the McNemar test for paired proportions[70], a method used elsewhere[31,56].

Output: Report summarising the relative out of hospital cardiac arrests coverage of the different deployment strategies, and outlining the optimisation model.

8 COST-EFFECTIVENESS OF OPTIMISED PLACEMENT STRATEGIES (WP3)

8.1 AIM

To determine the cost-effectiveness of implementing the optimised placement strategy compared to current placement.

8.2 OBJECTIVES

- To identify and quantify the costs and benefits of implementing the proposed optimisation strategy
- To explore the degree of uncertainty around key parameter and to determine the value of collecting further information on these parameters

8.3 PLAN OF INVESTIGATION

The analysis will involve building a decision analytic model, which will serve as a structure for quantifying the expected costs and outcomes of optimised placement and current placement from the perspective of the NHS and Personal Social Service. Different types of models that may be suitable for the particular decision problem will be explored, including state transition and individual sampling models[71,72]. In line with current recommendations, costs and benefits accruing in the future will be discounted to reflect positive time preference. All stages of the analysis will be carried out in line with widely accepted good practice recommendations[73-75].

Key parameters entering the model will include the probability of successful out-of-hospital resuscitation, relevant costs and health outcomes. Costs will include expenditure for purchase, installation and maintenance of defibrillators, basic training of individuals who are usually near the defibrillator and are likely to use it (e.g., individuals working nearby), ambulance costs, accident and emergency attendance costs, and costs related to use of inpatient and outpatient care. Outcomes will be measured in terms of life-years (LY) gained and quality-adjusted life years (QALYs), a widely used measure that combines expected survival and quality of life.

Input parameters will be assigned appropriate probability distributions to account for uncertainty in available estimates[76]. Final results will be presented in terms of incremental cost per additional LY and QALY gained. In line with recommendations, the impact of uncertainty in the final results will be explored through deterministic and probabilistic sensitivity analyses[77,78]. The latter allows generating a distribution of costs and outcomes, which will be depicted on a cost-effectiveness plane and will be plotted as cost-effectiveness acceptability curves (CEACs). CEACs will show the probability of current placement and optimised placement being cost-effective across a range of possible values of 'willingness to pay' for an additional unit of outcome[79]. Using the developed model, value of information analysis (expected value of perfect and parameter information) will be conducted to determine the value of, and the need for, conducting primary research to collect further information on key uncertain parameters[80,81].

Output: Report summarising the cost-effectiveness of the various deployment strategies.

9 SYNTHESIS AND STAKEHOLDER INVOLVEMENT (WP4)

9.1 AIM

Develop a national consensus of the optimal location for public-access AEDs

9.2 OBJECTIVE

- Present a synthesis of the evidence from previous work packages
- To develop a guidance document to advise key stakeholders on the optimal location for AEDs
- To develop a final report for submission to NIHR HSDR programme
- Identify priorities for future research

9.3 PLAN OF INVESTIGATION

Data and results of analyses from all previous work packages will be brought together and presented to stakeholders at a small consensus meeting to develop a guideline for stakeholders. In advance of the meeting the research team, PPI and expert panel will review all work package reports and develop a draft guideline report where options are suggested where evidence is uncertain or there is balancing of risks and benefits. Stakeholders will be identified with the help of our PPI and expert panel. We will aim for representatives of organisations involved purchasing and distribution AEDs for communities, and groups with an interest in the topic area. We will also contact organisations such as UK ambulance services, NHS England, Association of Ambulance Chief Executives, National Association of Ambulance Medical Directors, College of Paramedics, Resuscitation Council (UK), British Heart Foundation and other relevant national advocacy groups and charities to identify relevant participants. We hope to attract about 10-15 people to the meeting with a balance between health professionals and non-health professionals. Those representing charities along with PPI representatives will be reimbursed for time and expenses.

Meeting participants will receive in advance, reports from all work packages, the draft guidance document and details of the purpose and programme of the meeting. Mini-presentations of work package results and draft guidance will be presented. Afterwards participants will discuss the results and recommendations. A final plenary session will summarise the views and participants and way forward to producing a final report and guidance document. Finally, we will brainstorm on barriers and facilitators to implementation. During the meeting we will explore the need for further research and if relevant produce a prioritised list for future research needs.

After the meeting we will review meeting notes and records to check process and interpretation. Any problems identified will be resolved through email contact with participants. Notes will be analysed to further inform the final report and guidance documentation.

Output: Report summarising all work packages and consensus meeting, and guidance document on where to place AEDs to optimise patient outcomes and prioritised list of future research needs. Patient and public summary of findings.

10 STUDY ORGANISATION AND OVERSIGHT

10.1 SPONSOR AND GOVERNANCE ARRANGEMENTS

The project will be co-sponsored between University Hospitals Birmingham NHS Foundation Trust and University of Warwick. University Hospitals Birmingham NHS Foundation Trust will be the main contractor

with NIHR. They will sub-contract the delivery of the research to the University of Warwick. Ethical approval for the study will be sought from the University of Warwick's Biomedical and Scientific Research Ethics Committee (BSREC).

Annual reports will be submitted to the BSREC within 30 days of the anniversary date on which the favourable opinion was given, and annually until the study is declared ended. The BSREC will be notified of the end of the study (whether at planned time or prematurely).

The co-CI (Dr Brown) will submit a final report to the required authorities with the results, including any publications within one year of the end of the study.

10.2 Peer Review

This proposal has been subject to robust peer review during two rounds of assessment with the NIHR. This process has included evaluation of scientific merit, methodologic, statistical and health economic approaches. It has additionally been assessed by lay reviewers and the NIHR board. We believe this proposal meets the standards of high quality reviewed required by the NUHR CRN for adoption to their portfolio. That is, peer review was:

a) Independent: At least two individual experts reviewed the study.
b) Expert: Reviewers have knowledge of the relevant discipline to consider the clinical and/or service based aspects of the protocol, and/or have the expertise to assess the methodological and statistical aspects of the study.
c) Proportionate: Peer review should be commensurate with the size and complexity of the study.

10.3 Study Registration

The study is not eligible for ISRCTN or PROSPERO, and therefore will be registered on the Research Registry, https:www.researchregistry.com/.

10.4 Notification of breaches to GCP and/or study protocol

A breach which is likely to affect to a significant degree:

a) The safety or physical or mental integrity of subjects of the study; or
b) The scientific value of the study.

The sponsor will be notified immediately of any case where the above definition applies during the study conduct phase. The sponsor of a clinical study will notify the authorities in writing or any serious breach of:

a) The conditions and principles of GCP in connection with that study; or
b) The protocol relating to that study, as amended from time to time, within 7 days of becoming aware of that breach.

10.5 Indemnity

NHS indemnity covers NHS staff, medical academic staff with honorary contracts, and those conducting the study for instances of negligent harm. NHS bodies carry this risk themselves or spread it through the Clinical Negligence Scheme for Trusts, which provides unlimited cover for this risk. The University of Warwick provides indemnity for any harm caused to participants by the design or delivery of the research protocol.

10.6 Study Timetable and Milestones

The study will start on the 1st October 2019 and will run for 33 months. See Figure X Project Management Plan. We will provide progress reports after each six month period, which will report against the following milestones:

- Months 1-3: Confirmation of data sharing agreements with ambulance services and charities, study documents, ethics and governance approvals, contracts and staffing.
- Months 1-9: Complete current coverage of registered AEDs (WP1)
- Months 10-23: Complete comparison of AED deployment strategies and optimisation model (WP2)
- Months 24-29: Complete cost-effectiveness assessment of optimised placement strategies (WP3)
- Months 30-33: Complete synthesis and stakeholder involvement (WP4)
- Months 30-33: Draft final report

10.7 Administration

The study co-ordination will be based at WMS/WCTU, University of Warwick.

10.8 Study Management Group (SMG)

The Study Management Group, consisting of the project staff and co-investigators involved in the day-to-day running of the study, will meet regularly throughout the project. Significant issues arising from management meetings will be referred to the Study Steering Committee or Investigators, as appropriate.

10.9 Study Steering Committee (SSC)

The study will be guided by a group of respected and experienced personnel and researchers as well as least one 'lay' representative. Membership of the SSC is shown at the beginning of this protocol and will have an independent Chairperson.

The full remit and responsibilities of the SSC will be documented in the Committee Charter which will be signed by all members. In the development of this protocol, and throughout the study, the SSC will take responsibility for:

- Major decisions such as need to change the protocol for any reason
- Monitoring and supervising the progress of the study
- Reviewing relevant information from other sources
- Informing and advising on all aspects of the study

Face-to-face meetings will be held at regular intervals determined by need but not less than once a year. Routine business will be conducted by email, post or teleconferencing.

10.10 Expert Advisory Group (EAG)

The study will be informed by an expert advisory group (EAG) comprising key stakeholders who will guide the research team and help develop the new guideline. The EAG will:

- Support the research team to interpret findings from work packages
- Help formulate recommendations
- Advise on the content and delivery of outcomes to professional audiences.

The EAG will comprise representatives Association of Ambulance Service Chief Executives (AACE), National Ambulance Service Medical Directors group (NASMED), others

To ensure patient focus is not lost, our PPI co-applicant Me John Long will also be a member of the EAG. Membership of the EAG is shown on page X.

Face-to-face meetings will be held at regular intervals determined by need but not less than once a year. Routine business will be conducted by email, post or teleconferencing.

10.11 Data Monitoring Committee (DMC)

Since there is no intervention delivered as part of the study a DMC is not required. We are using a significant proportion of routinely collected data, so issues of safety should have been addressed by organisations collecting data as part of their audit processes.

10.12 Essential Documentation

A Study Master File will be set up according to WMS SOP and held securely at the WCTU.

10.13 Financial Support

The study has been funded by a grant from the National Institute of Health Research Health Services & Delivery Research Programme.

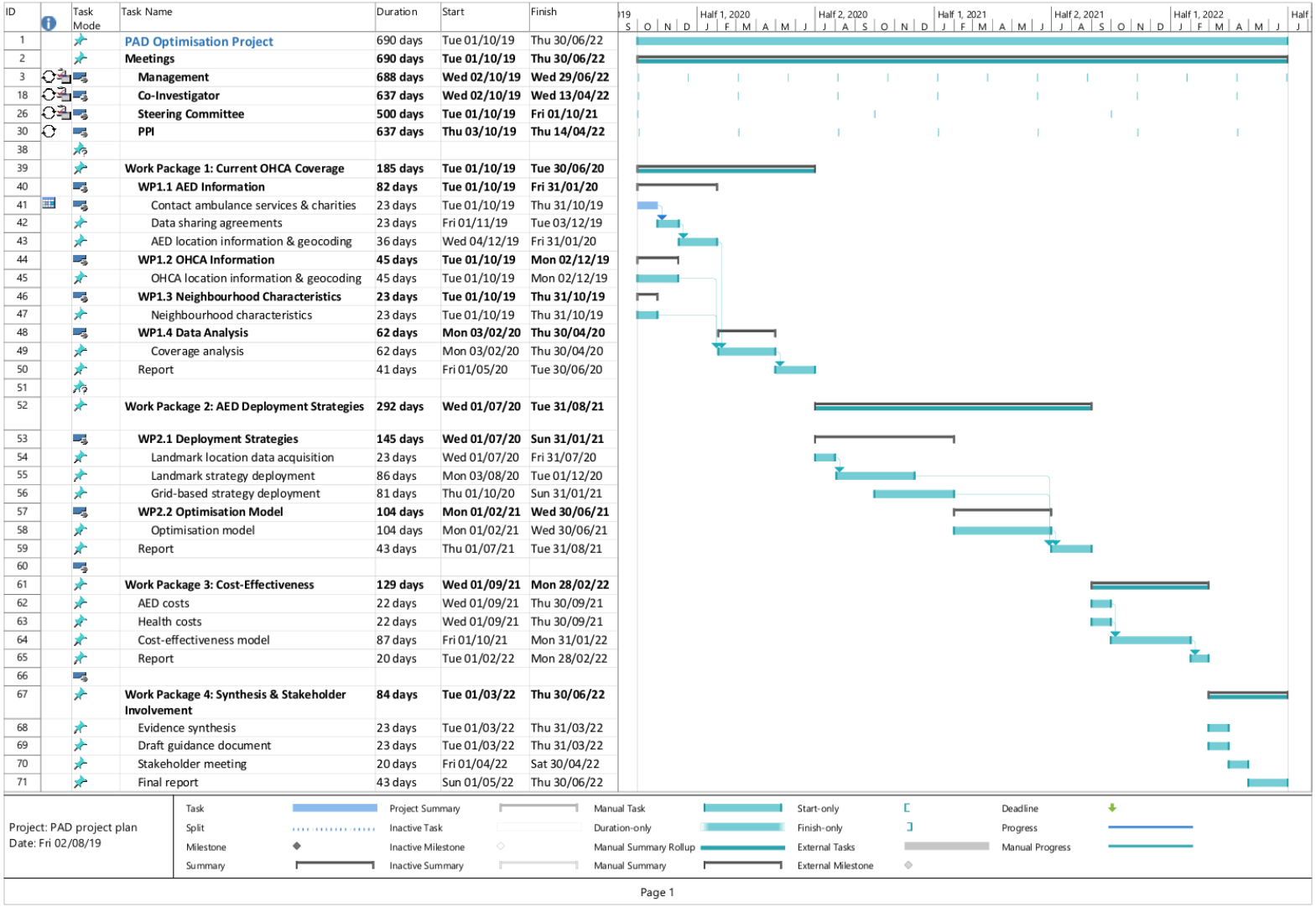

Figure 5: Project Gantt chart

11 MONITORING AND AUDIT

This research is limited to the secondary analysis of existing anonymised data. Formal monitoring of the study is not planned. The Sponsor, SMG or SSC may initiate an audit in the event of any concerns emerging during the conduct or following completion of the study.

Data quality checks will have been completed by the OHCAO registry, according to their protocols, prior to transfer of the clean anonymised data set to the PAD-Op study team for analysis.

12 PATIENT AND PUBLIC INVOLVEMENT (PPI)

Patient and public involvement (PPI) involvement is embedded throughout this research. Our co-applicant, Mr John Long, has been involved since the inception of this proposal and will be a core member of the research team, contributing to all aspects of the study. We have presented to the Clinical Research Ambassador Group (CRAG) at University Hospitals Birmingham NHS Foundation Trust and amended our study in line with their recommendations. They were supportive of our plans, felt the composition of the research team was appropriate. The CRAG felt this was an important question and were keen to maintain involvement if the project is funded.

At the outset of the project, we will convene a PPI advisory panel to advise on study design, materials and conduct, comment and advise the team on findings, help formulate recommendations and advise on the content and delivery of outcomes to lay audiences. In particular, the PPI panel ensure robust patient and public stakeholder representation at the consensus meeting (WP4). In addition our PPI co-applicant will also sit on our EAG to ensure PPI input is included and not lost among scientifically focused outcomes.

The PPI panel will comprise Mr John Long and up to three other members. We will endeavour to ensure as far as is practicable that there is a balance of members with respect to gender and as far as possible, of age group.

The University of Warwick has well established links with individuals who are keen to provide input into research undertaken at Warwick. In the first instance, we will invite individuals with an interest in cardiac arrest related research, who have worked with us on previous cardiac arrest related research. If too few individuals volunteer, we will extend the invitation to members of CRAG, and also Redditch and Hale Hearties support group, some of whom have already expressed an interest in working with us.

Face-to-face meetings will be held at regular intervals determined by need but not less than once a year. Routine business will be conducted by email, post or teleconferencing.

13 DISSEMINATION AND PUBLICATION

It is anticipated that this study will produce the following outputs:

- An optimal deployment model that will provide a guideline to stakeholders on where to locate AEDs
- Conference presentation at UK and European ambulance and resuscitation meetings
- Publications from each work package in peer-reviewed journals
- Final report that brings together the findings of all work packages
- Lay summary of research findings, including an infographic

Our dissemination strategy will aim to increase awareness of our findings, stimulate improvements in pre-hospital resuscitation, provide an evidence base for future research funding and promote public engagement and understanding of the research. It will target the following groups:

- Policy makers and commissioners
- Ambulance networks
- Health care providers
- Academic audiences
- Patients and public
- Resuscitation charities and advocacy groups
- AED manufacturers

We will ensure our patient and public contributors are involved in developing and implementing our dissemination plan. Their focus on improving care for victims of cardiac arrest gives them an insight which compliments the experiences of clinical and academic co-applicants. We have strong links with guideline development groups and our previous research has influenced several national and international guidelines. We will harness the contacts and professional networks of members of our expert advisory group, which contain key opinion leaders in resuscitation and pre-hospital care. This will ensure results are promulgated across all regional and national resuscitation related networks and to the highest policy making levels, to facilitate adoption of the completed work.

We have considered specific barriers to implementation using the framework by Fisher et al. (2016)[82]. Specific interventions to facilitate adoption include:

- Co-production of the guideline with the key stakeholders.
- Developing a clear, accessible, generalizable evidence-based guideline that is relevant to all stakeholders.
- Seeking endorsement of the guideline from key stakeholders.
- Developing an implementation guide and supporting materials.
- Audit and incorporate feedback into the national out-of-hospital cardiac arrest registry annual reports.
- Promoting public engagement throughout the project and sharing a plain language summary of our findings to patient and public representative organisations, including cardiac care advocacy groups.
- Creation of an evidence base through scientific papers published in high profile and speciality specific journals that provide open access and are widely read by the pre-hospital care, resuscitation, clinical and research communities.
- Presentation of findings at relevant national and international academic conferences. We will also develop supporting materials to assist dissemination at professional meetings.
- Publicising key scientific outputs by issuing press releases to established media contacts, making research team members available for interview and using our website, blog, Facebook page and Twitter feed.

We have the support of the NHS England, British Heart Foundation and Resuscitation Council (UK) (letters attached) and expect guidelines generated through this research will be included in any AED guidance documentation produced. The new guidance will assist government, charities, interested stakeholders, and individuals guide AED installation in uncovered high risk areas.

We have carefully considered the potential barriers to implementation using the framework developed by Fisher et al. (2016)[82]. Potential barriers include personal factors (knowledge attitudes and beliefs of stakeholders), guideline factors (lack of evidence, complexity, clarity, and layout) and external factors (organisational constraint, resources, lack of collaboration, social and clinical norms). Our dissemination strategy seeks to limit the effect of these barriers through key opinion leaders, providing an evidence base

for the guideline, involving patients and public so the recommendations are sensitive to their needs and views, and working with the key stakeholder organisations.

Our research will support the implementation of an evidence-based guideline on the optimal deployment of AEDs in the community which currently does not exist. It will improve the likelihood that a patient experiencing an out of hospital cardiac arrest will receive life-saving treatment before arrival of emergency services, and subsequently improve their healthcare quality and their families, by engaging clinicians, patients, ambulance services and policy makers to provide better care, by optimising the use of limited health resources.

Author and Collaborator Contributions

We will follow the guidance on authorship and contributions outlined by the ICMJE and Warwick CTU publication policy. This will ensure that all those that make a wholehearted contribution to this project and agree to be included, are named appropriately included in study outputs.

14 REFERENCES

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