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## Commentary and concepts

# Development of a centralised national AED (automated external defibrillator) network across all ambulance services in the United Kingdom



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### Abstract

**Background:** Early cardiopulmonary resuscitation and defibrillation is key to increasing survival following an out-of-hospital-cardiac-arrest (OHCA). However, automated external defibrillators (AEDs) are used in a very small percentage of cases. Despite large numbers of AEDs in the community, the absence of a unified system for registering their locations across the UK's ambulance services may have resulted in missed opportunities to save lives. Therefore, representatives from the resuscitation community worked alongside ambulance services to develop a single repository for data on the location of AEDs in the UK.

**Methods:** A national defibrillator network, "The Circuit", was developed by the British Heart Foundation in collaboration with the Association of Ambulance Chief Executives, the UK ambulance services, the Resuscitation Council UK and St John Ambulance. The database allows individuals or organisations to record information about AED location, accessibility, and availability. The database synchronises with ambulance computer aided dispatch systems to provide UK ambulance services with real-time information on the nearest, available AED.

**Results:** The Circuit was successfully rolled out to all 14 UK ambulance services. Since 2019, 82,108 AEDs have been registered. Of the AED data collected by The Circuit, 54% were not previously registered to any ambulance service, and are therefore new registrations.

**Conclusion:** The Circuit provides ambulance services with a single point of access to AED locations in the UK. Since the launch of the system the number of defibrillators registered has doubled. Linking the Circuit data with patient outcome data will help understand whether improving the accessibility to AEDs is associated with increased survival.

**Keywords:** AED, The Circuit, National Defibrillator Network

## Introduction

Automated External Defibrillators (AEDs) for public use are essential to improve outcomes of out of hospital cardiac arrests (OHCA).<sup>1–3</sup> For an AED programme to be effective, the dispatch centres for the emergency services need access to reliable information on AED location and availability.<sup>4–7</sup>

In 2015, the British Heart Foundation (BHF) commissioned University of Warwick to carry out a mixed methods study comprising of the exploration of international practice and a rapid review of the literature. The study,<sup>5</sup> identified variation in approaches used by UK ambulance services to AED registration, sub-optimal capture of available AEDs (only 32,000 of an estimated 100,000 AEDs were registered), and problems with maintaining an accurate record of AED location and availability. Despite innovative and successful

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programmes, such as the Save a Life<sup>8</sup> and GoodSAM<sup>9</sup> applications, the lack of a single and consistent approach highlighted the need to develop a national AED database.<sup>10</sup>

With the support of the Association of Ambulance Chief Executives (AACE), charitable and clinical partners, BHF committed to develop and provide the initial funding for a national defibrillator network. This paper describes the development of the minimum viable product specification, design and initial implementation and roll out of The Circuit: the national defibrillator network (the UK's national AED network).

## Methods

### Study setting

The United Kingdom (UK) includes the three countries within Great Britain (England, Scotland and Wales) and Northern Ireland. The UK covers 248,532 km<sup>2</sup> with a population of 67,026,292 people.<sup>11</sup> The pre-hospital care of patients with OHCA are provided by the National Health Service (NHS) through 14 ambulance services which cover the 4 nations of the UK. Members of the public can contact the ambulance service by calling the national emergency service telephone number 999 where calls are initially directed to a central operator (technician) who will determine the most appropriate emergency service to allocate the call to. Calls received by the ambulance service are managed using one of 3 computer aided dispatch (CAD) systems: Cleric Computer Systems, (Cheshire, England), MIS Emergency Systems, (Cheshire, England) and Hexagon, (Stockholm, Sweden). When a cardiac arrest is identified or suspected, an ambulance is dispatched immediately along with other available responders. The call handler is prompted to initiate telephone CPR instructions. Prior to implementation of the Circuit, the CAD system would either automatically identify the nearest available AED or the call handler would search the AED register manually. All 14 ambulance services worked on a minimum of 200 m radius (range 200–1600 m) around the event for the CAD to search for an AED. If there are AEDs within this radius and in an emergency ready status, then the dispatcher will check through the list and ask the caller to send another bystander to collect this AED while CPR is being carried out. This includes verbally providing the bystander with the location details and, if needed, the code required to unlock the cabinet to access the AED. Members of the public and community first responders can find the nearest AED by looking it up on the web application Defibfinder (<https://www.defibfinder.uk>). An evolution of the programme would be to share the data with other platforms that allow the ambulance service to alert members of the public to an OHCA.

### Developing a minimum viable product

In 2018, BHF invited the UK ambulance services to support them in developing The Circuit. The West Midlands (WMAS) and the Scottish (SAS) ambulance services volunteered to take part in the initial phase of the programme. Employees from both services were involved in the end-to-end process for developing The Circuit, including appointing suppliers, agreeing the requirements and testing it in a live environment. There were two types of CAD in use between WMAS and SAS and each supplier was involved in the requirements gathering stage of the process and in testing the system. [Table 1](#) outlines the high-level overview of the technical requirements for The Circuit.

The Circuit was developed on the Microsoft (MS) Azure SQL platform and is hosted in its own MS Tenant (Azure UK South) and consists of two Azure subscriptions.

Each ambulance service nominates individuals to act as administrators on The Circuit. Each administrator needs to register for an account so they can view AEDs on The Circuit in their own region. Registered administrators can also view the contact details for Guardians within their own region. A Guardian is the term used within The Circuit for the individual(s) responsible for looking after an AED(s). Ambulance service administrators are also provided with access to further data and reports using the MS data visualisation platform known as Power BI (Business Intelligence) hosted on MS Azure SQL platform (Azure UK South).

The Circuit is compliant with UK General Data Protection Regulation, the Data Protection Act 2018 and with International Organization for Standardization (ISO) 27001 security standards.

### AED guardians and owners

The Circuit developed a system whereby AED Guardians were able to register fixed location AEDs on the defibrillator database. They commit to checking the AED regularly, cleaning it and replacing consumables after it has been used in an emergency and in replacing consumables on expiry (funding models for consumables vary). Guardians need to set up an account on The Circuit before they can register an AED. Thereafter, they will receive regular automated emails every 3 months prompting them to update their record on The Circuit (see process flow). The system is designed to prevent Bots from registering AEDs.

The owner of the AED may also act as a Guardian, or in the case of large commercial or charitable organisations, the owner may not be the same as the Guardian. For example, in some situations, the owner of the AEDs will be a supermarket or hotel chain and the Guardians will be the local supermarket or hotel staff who are onsite in that location and can check the AED regularly.

### AED registration

The Circuit records the registration of fixed AEDs in public locations (for example train stations or shopping centres) as well as locations where access is restricted to authorised personnel such as staff for commercial premises or members of sports clubs. Mobile AEDs carried by trained first responders (including police or fire fighters) are not registered.

AEDs are registered through an online front-end portal on The Circuit website. AED Guardians and owners can register AEDs one by one, or by using the bulk upload process (for 10 s, 100 s, 1000 s of AEDs) using a bespoke MS Excel file. The bulk upload process is typically used by not-for-profit or commercial organisations that are responsible for more than 10 AEDs over a large geographical region. It requires one member of the organisation to register an organisation account before uploading the completed MS Excel file. The tasks required of Guardians are outlined in [figure 1](#).

[Table 2](#) presents the data field captured at the time of registration.

### Continuous improvement of the product and national implementation

The BHF worked with each ambulance service and with AED Guardians to continuously improve The Circuit based on user feedback. Initially, The Circuit allowed ambulance services to view the data

within their own catchment area but was later enhanced to allow all ambulance services to see UK-wide data required in an emergency (such as location, emergency readiness and availability).

In response to public demand, subject to permission being granted by the registered Guardian, information on AED locations, availability and status is also pushed to a publicly accessible web application known as 'DefibFinder',<sup>12</sup> to allow members of the public to identify the location of the ten nearest AEDs to any postcode. The majority (95.7%) of registered Guardians provide permission for their AED location to be shared on DefibFinder.

### **Marketing campaigns**

BHF and the ambulance services developed an email campaign to Guardians who had previously registered their AEDs directly with the ambulance services. The campaign was time-limited and consisted of three emails inviting the Guardians to register their AEDs on The Circuit. The email campaigns to this group were executed either by the ambulance services through their standard in-house email platforms or through a third-party direct response marketing agency, who delivered the campaign on their behalf. The agency used an email marketing platform that allowed for non-deliverable emails, open rates, and other key performance indicators to be measured, allowing for a more effective campaign to be executed.

BHF also worked with RCUK and SJA to develop a mass acquisition campaign targeting Guardians who had not previously registered their AEDs with the ambulance services. An integrated marketing campaign was developed that included owned, earned and paid channels, including emails to all eligible partner databases where General Data Protection Regulation permissions allowed, website landing pages, paid social channels, and paid search. The campaign used a full funnel approach that generated awareness, consideration and conversion. Awareness of The Circuit and the benefits of registering was delivered through PR activity before targeted activity was delivered to likely AED owners/Guardians to act (conversion) and register their AEDs. The campaign targeted likely owners/Guardians of AEDs, such as parish councils, sports clubs and corporates.

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## **Results**

The data set out in this paper covers from 11/06/2019 up to 31/12/2023.

### **Ambulance service rollout**

Over a period of four years, The Circuit was implemented in all 14 of the UK's ambulance services. The West Midlands and Scottish Ambulance Service were the first two services to go live in July and August 2019 respectively. Three additional services went live prior to implementation being paused in March 2020 during the Covid-19 pandemic. Implementation resumed in 2021 to the 9 remaining ambulance services in England and completed in September 2022.

### **Registered AEDs**

In 2015, as part of the feasibility carried out by Warwick University, the ambulance services reported they had logged the location of approximately 32,000 AEDs. However, the ambulance services reported data quality issues as there were no formal processes in place to update the data and in some cases the data were several

years old. As of 31/12/2023, there were 82,108 AEDs registered by a named Guardian on The Circuit (figure 2) representing a 157% increase in what the ambulance services had reported in 2015. A data deduplication exercise carried out with the ambulance services where the legacy data (held on each CAD prior to linking to The Circuit) and the data registered on The Circuit, suggests that approximately 54% of the AEDs registered on The Circuit were previously unknown to the ambulance services.

Amongst these 82,108 are registered in England, 3,058 in Northern Ireland, 7,410 in Scotland, 7,162 in Wales.

Out of the 82,108 registered AEDs, 71.4% are classed as publicly accessible meaning any member of the public can access them if needed. The remainder are classed as restricted access which means that access to the AED is restricted to people with access to the building/location. Emergency readiness was recorded at noon each day and as of 31/12/2023, 87% were emergency-ready and 13% were out-of-service.

### **AED Guardians and organisation accounts**

As of 31/12/2023 there are 55,235 AED Guardians who have registered AEDs and continue to maintain them. There are 453 organisational accounts such as a charity, commercial or private company that owns and manages AEDs who are managed by organisational administration accounts.

### **Improved data availability**

Prior to The Circuit, ambulance services reported delays of up to three weeks from having first received location data on an AED from the Guardian to manually uploading it onto ambulance service CADs. The Circuit enables AED data to be on every ambulance service CAD, within 60 s of the AED being registered by a Guardian.

Since The Circuit went live and up until 31/12/2023, the ambulance services have reported the deployment of AEDs (sent a bystander to fetch it) on 113,811 occasions.

Previously, each service had access to local data only, making them less effective when handling OHCA calls for other ambulance services. At the time of publication, ambulance services within England and Wales can see AED location data across the entire geographic region enabling each service to direct bystanders to the nearest AED when handling calls for a different service. It is the intention of the ambulance service in Scotland to adjust their CAD to facilitate the access to location data for defibrillators in England and Wales. The Northern Ireland ambulance service cannot access this functionality as it is geographically separate from mainland Britain and uses a different mapping system.

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## **Discussion**

The Circuit provides a single point of access for up-to-date information on AEDs across all UK ambulance services. The system avoids loss of information between artificial boundaries created by ambulance service areas of operation. The development of a novel AED Guardianship programme enables real time availability to be shared with ambulance services. A programme to enhance registration of AEDs has led to a doubling in the number of AEDs registered as accessible to ambulance services. These interventions are anticipated to play a key role in improving access to AEDs in the UK and consequently to improve survival from OHCA.

Studies have shown that the chance of surviving an OHCA can double when a defibrillator is nearby.<sup>13</sup> Optimising the availability, reliability and usability of an AED at the time of an OHCA is one of several key strategies identified to improve outcomes after an OHCA. However, many factors can affect AED availability at the time of a cardiac arrest, including the ability of bystanders and/or emergency services to locate the nearest available and emergency-ready AED in a timely manner.<sup>4</sup>

In 2007, Denmark became the first country to develop a national AED registry, which has been available to all five nationwide Emergency Medical Dispatch Centres since 2010.<sup>14</sup> Other countries or cities have also developed similar registries at a different scale, including Philadelphia<sup>15</sup> and Sweden<sup>16</sup>; with some countries making AED registration mandatory through legislation to develop comprehensive databases, including France.<sup>17</sup> There is evidence from Denmark, that the registration of AEDs on an established national registry is a contributing factor to an increase in bystander defibrillation and an associated increase in OHCA 30-day survival rate.<sup>13</sup>

Prior to The Circuit each of the 14 ambulance services in the UK maintained separate databases of defibrillators, of varying degrees of sophistication, with support from multiple charities providing data using manual upload processes. In addition, there were several charities mapping AED location including the Save a Life application,<sup>8</sup> and GoodSam application<sup>9</sup> which used crowdsourcing to identify AED locations. Other countries also used crowdsourcing to populate AED registries (MyHeart-Map Challenge, Philadelphia).<sup>15</sup>

Capturing key information about the location, emergency readiness status, expiry date and contact information of the person responsible for the device can facilitate maintenance and therefore readiness and successful use when required.<sup>4</sup>

Other countries have used their AED registries to optimise the geographic distribution of AEDs by comparing the AED locations to geographic cardiac arrest data, including Singapore<sup>18</sup> or Georgia (US).<sup>19</sup> This could also be feasible in the UK by linking The Circuit dataset with other datasets, such as the OHCA Outcomes Audit.<sup>20</sup> Given that AEDs placement in local communities can be uncoordinated,<sup>21</sup> analysis of the data held on The Circuit and other datasets could help to reduce health inequalities if AED funding were subsequently directed towards areas with high rates of OHCA and low provision of AEDs.

The data generated from The Circuit provides unique opportunities for future research. Information on AED deployment rate have the potential to inform consensus on optimal criteria for deployment of an AED. Quantitative and qualitative data from the novel Guardianship system could provide rich insights into Guardian's preferences and behaviours. Analysis of AED locations relative to the risk of cardiac arrest and socio-economic characteristics of communities at risk provide an opportunity to tackle health inequalities. Data from the Circuit has the opportunity to provide additional insights into the benefits and harms of placing AEDs in locked versus unlocked cabinets as locked cabinets are common in the UK.

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## Challenges

The data quality is reliant upon the actions of over 55 K individuals updating The Circuit regularly about analogue AEDs. It is therefore inevitable that there are instances when the data are out-of-date while awaiting action from an AED Guardian. It is likely that the introduction of smart AEDs will reduce the dependency on human inter-

vention and that some data fields (emergency readiness, geo-location) will be captured automatically.<sup>4</sup>

Unlike other countries such as Italy<sup>22</sup> and France,<sup>19</sup> it is not mandatory for an AED owner or Guardian to register their AED with The Circuit or with the ambulance services in the UK. AEDs are sold from multiple sources and therefore, we cannot be certain that we have mapped every AED in-situ in the UK. It is likely that tens of thousands of AEDs in the UK remain unregistered. It highlights the need for ongoing awareness of The Circuit and the value in registering AEDs.

Measuring the impact of The Circuit on the OHCA survival rates will require data linkage and will need to be observed over a period of years. It will not be possible to directly attribute lives saved to The Circuit, but it is anticipated that it will be a contributing factor over time. We are exploring how we can capture data on the rate of use of registered defibrillators at the scene of an OHCA. There is an ongoing programme to analyse the reported rate of theft and vandalism in locked and unlocked cabinets.

Delivery of The Circuit programme includes continuous enhancement of the technology, analysis of the data, regular engagement across the 14 ambulance services to capture their feedback for improvement, delivery of a customer journey to maintain guardian engagement and marketing to increase the number of defibrillators registered. The programme is delivered by the BHF. There are discussions in progress between BHF and the other funders on the long-term sustainability plan for The Circuit.

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## Conclusion

The Circuit provides ambulance services with a single point of access to most AED locations in the UK. Defibrillator Guardians play a key role in providing up to date information about AED readiness for deployment. Since the launch of the system the number of defibrillators registered has more than doubled. Linking the Circuit data with patient outcomes data will help understand whether improving the accessibility to AED is associated with increased survival.

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BHF solely funded The Circuit from 2018 until April 2023. BHF remains the majority funder but from April 2023, NHS England, Resuscitation Council UK and St John Ambulance have contributed to the funding.

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## CRedit authorship contribution statement

**Judy O'Sullivan:** Writing – original draft, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization. **Edward Moore:** Writing – review & editing, Visualization, Resources, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Simon Dunn:** Writing – review & editing, Resources, Project administration, Conceptualization. **Helen Tennant:** Writing – review & editing, Resources, Project administration, Methodology, Conceptualization. **Dexter Smith:** Writing – review & editing, Resources, Project administration, Methodology, Conceptualization. **Sarah Black:** Writing – review & editing, Resources, Project administration, Methodology. **Sarah Yates:** Writ-



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### Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: ‘Authors listed as affiliated to the BHF are employees of the BHF, a registered charity in England and Wales, Scotland and the Isle of Man. The BHF is the main funder of The Circuit and responsible for its administration. The author listed as affiliated to NHS England (NHSE) is a former employee of NHSE. NHSE is a co-funder of The Circuit. Authors listed as affiliated to the Resuscitation Council UK (RCUK) are employees of the Resuscitation Council UK a registered charity in England and Wales. The RCUK is a co-funder of The Circuit. Authors listed as affiliated to St John Ambulance (SJA) are employees of St John Ambulance a registered charity in England. SJA is a co-funder of The Circuit. Simon Dunn, Steve Irving, Sue Hampshire, Michael Bradfield, Charles Deakin, Simon Holmes, Stephanie Leckey, Nick Linker, Greg Lloyd, Julian Mark, Lisa McInnes, Simon Walsh, George Woods, Judy O’Sullivan and Gavin D Perkins are current or former members of The Circuit National Advisory Board. GDP holds research grants from the BHF, Resuscitation Council UK and the Laerdal Foundation, is a Trustee for the Resuscitation Council UK and Editor for Resuscitation and Resuscitation Plus journals.’

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### Appendix A. Supplementary material

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