

**A Thesis Submitted for the Degree of PhD at the University of Warwick**

**Permanent WRAP URL:**

<http://wrap.warwick.ac.uk/159729>

**Copyright and reuse:**

This thesis is made available online and is protected by original copyright.

Please scroll down to view the document itself.

Please refer to the repository record for this item for information to help you to cite it.

Our policy information is available from the repository home page.

For more information, please contact the WRAP Team at: [wrap@warwick.ac.uk](mailto:wrap@warwick.ac.uk)

**Improving public-access Automated  
External Defibrillator use in a volunteer  
first-responder system for out-of-  
hospital cardiac arrest**

**Christopher Matthew Smith**

A thesis submitted in fulfilment of the requirements for the degree of  
Doctor of Philosophy in Health Sciences

University of Warwick  
Warwick Medical School  
November 2020

# CONTENTS

<u>List of figures</u>	<u>9</u>
<u>List of tables</u>	<u>10</u>
<u>Abbreviations</u>	<u>12</u>
<u>Acknowledgements</u>	<u>14</u>
<u>Declaration</u>	<u>15</u>
<b><u>Abstract</u></b>	<b><u>17</u></b>

## INTRODUCTION

<b><u>Chapter 1: The community response to out-of-hospital cardiac arrest</u></b>	<b><u>18</u></b>
1.1 <u>Reporting out-of-hospital cardiac arrest</u>	<u>19</u>
1.2 <u>Epidemiology</u>	<u>21</u>
1.3 <u>Outcomes</u>	<u>22</u>
1.3.1 <u>Survival</u>	<u>22</u>
1.3.2 <u>Longer-term outcomes</u>	<u>23</u>
1.4 <u>The Chain of Survival concept</u>	<u>24</u>
1.5 <u>The role of the ambulance dispatcher</u>	<u>26</u>
1.5.1 <u>Recognising out-of-hospital cardiac arrest</u>	<u>26</u>
1.5.2 <u>Dispatcher-assisted CPR</u>	<u>28</u>
1.6 <u>Bystander CPR</u>	<u>29</u>
1.7 <u>Bystander public-access AED use</u>	<u>31</u>
1.8 <u>Other factors</u>	<u>31</u>
1.9 <u>Improving survival</u>	<u>33</u>
1.9.1 <u>Strategies to improve survival over time</u>	<u>33</u>
1.9.2 <u>The UK perspective</u>	<u>35</u>
1.10 <u>Public Access Defibrillation</u>	<u>36</u>
1.11 <u>Clinical effectiveness of PAD</u>	<u>36</u>
1.11.1 <u>Systematic review and meta-analysis findings</u>	<u>36</u>
1.11.2 <u>Randomised Controlled Trials</u>	<u>39</u>
1.11.3 <u>The UK perspective</u>	<u>40</u>
1.11.4 <u>Other observational studies</u>	<u>41</u>
1.12 <u>Cost-effectiveness of PAD</u>	<u>44</u>
1.13 <u>First-responders for OHCA</u>	<u>46</u>
1.14 <u>Volunteer first-responder systems</u>	<u>47</u>
1.14.1 <u>Systematic review</u>	<u>48</u>
1.14.2 <u>Observational studies</u>	<u>48</u>
1.15 <u>Optimising volunteer first-responder systems</u>	<u>50</u>

1.16	<u>Volunteer first-responders - ongoing research</u>	51
1.17	<u>Chapter conclusion</u>	52

## AIMS AND METHODS

<b>Chapter 2: Thesis Aims and Objectives</b>		<b>54</b>
2.1	<u>Introduction</u>	55
2.2	<u>Aim</u>	55
2.3	<u>Objectives</u>	56
<b>Chapter 3: General methods</b>		<b>57</b>
3.1	<u>Barriers and facilitators to Public Access Defibrillation (chapter 4)</u>	58
3.2	<u>A description of the GoodSAM first-responder system (chapter 5)</u>	58
3.3	<u>GoodSAM evaluation and Automated External Defibrillator use (chapter 6 and chapter 7)</u>	59
3.3.1	<u>Ethical approval and data sharing</u>	59
3.3.2	<u>Data collection</u>	60
3.3.3	<u>Data analysis</u>	63
3.4	<u>An investigation of AED use by GoodSAM first-responders (chapter 8 and chapter 9)</u>	63
3.4.1	<u>Ethical approval</u>	64
3.4.2	<u>Data collection</u>	64
3.4.3	<u>Data analysis</u>	65
3.5	<u>Determining the optimum activation distance for GoodSAM first-responders alerted to a nearby out-of-hospital cardiac arrest (chapter 10)</u>	67
3.5.1	<u>Ethical approval and data sharing</u>	67
3.5.2	<u>Data collection</u>	67
3.5.3	<u>Data analysis</u>	71
3.6	<u>Data storage</u>	71
3.6.1	<u>Written data</u>	72
3.6.2	<u>Visual and mapping data</u>	72
3.6.3	<u>Interviews</u>	73
3.6.4	<u>Archiving</u>	73
3.7	<u>Study oversight</u>	74
3.7.1	<u>Supervisors</u>	74
3.7.2	<u>Steering committee</u>	74
3.7.3	<u>Patient and Public Involvement</u>	75
3.7.4	<u>Funding</u>	76
3.8	<u>Reporting results</u>	76

## OUTPUTS

<b>Chapter 4: Barriers and facilitators to Public Access Defibrillation in out-of-hospital cardiac arrest</b>		<b>78</b>
4.1	<u>Introduction</u>	79
4.2	<u>Aim</u>	80
4.3	<u>Methods</u>	80
4.3.1	<u>Published systematic review (2017)</u>	80
4.3.2	<u>Update (2020)</u>	82
4.4	<u>Results: published systematic review (2017)</u>	82
4.4.1	<u>Knowledge and awareness</u>	86
4.4.2	<u>Willingness to use</u>	86
4.4.3	<u>Acquisition and maintenance</u>	88
4.4.4	<u>Availability and accessibility</u>	88
4.4.5	<u>Training issues</u>	89
4.4.6	<u>Registration and regulation</u>	90
4.4.7	<u>Medicolegal issues</u>	91
4.4.8	<u>Dispatch-assisted AED use</u>	91
4.4.9	<u>AED locator systems</u>	92
4.4.10	<u>Demographic factors</u>	92
4.4.11	<u>Human factors</u>	93
4.5	<u>Results: Update (2020)</u>	94
4.5.1	<u>Knowledge and awareness</u>	94
4.5.2	<u>Willingness to use</u>	94
4.5.3	<u>Acquisition and maintenance</u>	94
4.5.4	<u>Availability and accessibility</u>	95
4.5.5	<u>Training issues</u>	96
4.5.6	<u>Registration and regulation</u>	96
4.5.7	<u>Dispatch-assisted AED use</u>	96
4.5.8	<u>Demographic factors</u>	96
4.5.9	<u>Human factors</u>	97
4.5.10	<u>Drone delivery of AEDs</u>	97
4.6	<u>Discussion</u>	98
4.6.1	<u>Main findings</u>	98
4.6.2	<u>Comparison with the literature</u>	98
4.6.3	<u>Strengths and limitations</u>	100
4.6.4	<u>Clinical implications</u>	102
4.6.5	<u>Next steps</u>	102
4.7	<u>Conclusion</u>	103

<b>Chapter 5: The GoodSAM first-responder app for out-of-hospital cardiac arrest</b>	<b>104</b>
5.1 <u>Development</u>	105
5.2 <u>Governance</u>	106
5.3 <u>Integration with UK local ambulance services</u>	109
5.4 <u>Functionality</u>	112
5.4.1 <u>OHCA response</u>	112
5.4.2 <u>Other uses</u>	114
5.5 <u>Conclusion</u>	115

**Chapter 6: The effect of the GoodSAM first-responder app on survival to hospital discharge following out-of-hospital cardiac arrest** **116**

6.1 <u>Introduction</u>	117
6.2 <u>Aim</u>	117
6.3 <u>Methods</u>	117
6.3.1 <u>System description</u>	117
6.3.2 <u>Data sources</u>	118
6.3.3 <u>Data collection</u>	119
6.3.4 <u>Analysis and reporting of OHCA data</u>	121
6.3.5 <u>Ethical approvals</u>	123
6.4 <u>Results</u>	123
6.4.1 <u>OHCA incidence</u>	123
6.4.2 <u>GoodSAM alerts</u>	124
6.4.3 <u>Patient and process variables</u>	125
6.4.4 <u>OHCA outcomes</u>	128
6.4.5 <u>OHCA survival – logistic regression modelling</u>	129
6.5 <u>Discussion</u>	135
6.5.1 <u>Main findings</u>	135
6.5.2 <u>Comparison with the literature</u>	136
6.5.3 <u>Strengths and limitations</u>	137
6.5.4 <u>Clinical implications</u>	140
6.5.5 <u>Next steps</u>	143
6.6 <u>Conclusion</u>	143

**Chapter 7: The potential for bystander public-access Automated External Defibrillator use in out-of-hospital cardiac arrest** **144**

7.1 <u>Introduction</u>	145
7.2 <u>Aim</u>	146
7.3 <u>Methods</u>	146
7.3.1 <u>Data sources</u>	146
7.3.2 <u>Mapping OHCA and public-access AED locations</u>	147

7.3.3	<u>Spatial and data analysis</u>	150
7.3.4	<u>Ethical approvals</u>	151
7.4	<u>Results</u>	152
7.4.1	<u>Number of OHCAs and public-access AEDs</u>	152
7.4.2	<u>Proximity of OHCAs to public-access AEDs</u>	154
7.5	<u>Discussion</u>	157
7.5.1	<u>Main findings</u>	157
7.5.2	<u>Comparison with the literature</u>	158
7.5.3	<u>Strengths and limitations</u>	158
7.5.4	<u>Clinical implications</u>	161
7.5.5	<u>Next steps</u>	163
7.6	<u>Conclusion</u>	164

**Chapter 8: Barriers and facilitators to Automated External Defibrillator use by volunteers in the GoodSAM first-responder system** **165**

8.1	<u>Introduction</u>	166
8.1.1	<u>Out-of-hospital cardiac arrest</u>	166
8.1.2	<u>The GoodSAM first-responder app</u>	166
8.2	<u>Aim and objectives</u>	168
8.3	<u>Methods</u>	168
8.3.1	<u>Methodological approach: use of a theoretical framework</u>	168
8.3.2	<u>Participants</u>	170
8.3.3	<u>Interview process</u>	170
8.3.4	<u>Transcription, coding and analysis</u>	174
8.3.5	<u>Ethical considerations</u>	175
8.4	<u>Results</u>	175
8.4.1	<u>Capability</u>	179
8.4.2	<u>Opportunity</u>	180
8.4.3	<u>Motivation</u>	186
8.5	<u>Discussion</u>	193
8.5.1	<u>Main findings</u>	193
8.5.2	<u>Comparison with the literature</u>	194
8.5.3	<u>Strengths and limitations</u>	195
8.5.4	<u>Clinical implications</u>	199
8.5.5	<u>Next steps</u>	200
8.6	<u>Conclusion</u>	200

**Chapter 9: Developing theoretically-informed interventions to improve Automated External Defibrillator use by GoodSAM first-responders** **202**

9.1	<u>Introduction</u>	203
-----	---------------------	-----

9.2	<u>Aim</u>	204
9.3	<u>Methods</u>	205
9.3.1	<u>Information sources</u>	205
9.3.2	<u>Using the Behaviour Change Wheel</u>	205
9.3.3	<u>Ethical approvals</u>	209
9.4	<u>Results</u>	209
9.4.1	<u>Step 1: Define the problem in behavioural terms</u>	209
9.4.2	<u>Step 2: Select target behaviour</u>	213
9.4.3	<u>Step 3: Specify the target behaviour</u>	213
9.4.4	<u>Step 4: Identify what needs to change</u>	218
9.4.5	<u>Step 5: Identify intervention functions</u>	220
9.4.6	<u>Step 6: Identify policy categories; Step 7: Identify behavioural change techniques; Step 8: Identify modes of delivery</u>	233
9.5	<u>Discussion</u>	237
9.5.1	<u>Main findings</u>	237
9.5.2	<u>Comparison with the literature</u>	237
9.5.3	<u>Strengths and limitations</u>	238
9.5.4	<u>Clinical implications</u>	240
9.5.5	<u>Next steps</u>	241
9.6	<u>Conclusion</u>	241

**Chapter 10: Determining the optimum activation distance for GoodSAM first-responders alerted to a nearby out-of-hospital cardiac arrest** **242**

10.1	<u>Introduction</u>	243
10.2	<u>Aim and objectives</u>	244
10.3	<u>Methods</u>	245
10.3.1	<u>System description</u>	245
10.3.2	<u>Data sources</u>	245
10.3.3	<u>Data collection</u>	246
10.3.4	<u>Data storage</u>	248
10.3.5	<u>Data analysis and reporting</u>	248
10.3.6	<u>Ethical approvals</u>	253
10.4	<u>Results</u>	253
10.4.1	<u>London – all GoodSAM alerts</u>	253
10.4.2	<u>London – confirmed OHCAs</u>	263
10.4.3	<u>East Midlands – all GoodSAM alerts</u>	268
10.4.4	<u>East Midlands – confirmed OHCAs</u>	274
10.4.5	<u>Data validation</u>	279
10.5	<u>Discussion</u>	279
10.5.1	<u>Main findings</u>	279

10.5.2	<u>Comparison with the literature</u>	<u>281</u>
10.5.3	<u>Strengths and limitations</u>	<u>282</u>
10.5.4	<u>Clinical implications</u>	<u>286</u>
10.5.5	<u>Next steps</u>	<u>288</u>
10.6	<u>Conclusion</u>	<u>288</u>

## THESIS SUMMARY

<b>Chapter 11: Thesis Discussion</b>	<b><u>290</u></b>
11.1 <u>Main findings</u>	<u>291</u>
11.2 <u>Comparison with the literature</u>	<u>292</u>
11.3 <u>Strengths and limitations</u>	<u>297</u>
11.4 <u>Clinical implications</u>	<u>301</u>
11.5 <u>Next steps</u>	<u>306</u>
<b>Chapter 12: Thesis Conclusion</b>	<b><u>308</u></b>

## REFERENCES AND APPENDICES

<b>Chapter 13: References</b>	<b><u>310</u></b>
<b>Chapter 14: Appendices</b>	<b><u>330</u></b>
14.1 <u>Systematic review (chapter 4)</u>	<u>331</u>
14.1.1 <u>Electronic search strategies</u>	<u>331</u>
14.1.2 <u>Data collection form</u>	<u>331</u>
14.2 <u>Interview study (chapter 8)</u>	<u>352</u>
14.2.1 <u>Participant Information Sheets</u>	<u>352</u>
14.2.2 <u>Consent forms</u>	<u>364</u>
14.2.3 <u>Interview schedule and topic guides</u>	<u>366</u>
14.2.4 <u>Warwick Clinical Trials Unit 'Sensitive Interview Action' card</u>	<u>372</u>

## LIST OF FIGURES

Figure 1.1:	The Utstein template: core and supplemental data	20
Figure 1.2:	The Chain of Survival	25
Figure 1.3:	Bystander interventions and one-year risk of death and brain damage / nursing home admission (Point estimates and 95% CI)	43
Figure 4.1:	Study selection process, based on PRISMA flow diagram	84
Figure 4.2:	Barriers and facilitators to Public Access Defibrillation. Key Themes	85
Figure 5.1:	GoodSAM alert (simulated)	111
Figure 7.1:	An example of an AED location displayed on Google Maps at London Victoria Rail Station	149
Figure 7.2:	The GoodSAM app, displaying the location of nearby AEDs	149
Figure 7.3:	Geographical regions of interest for this chapter	152
Figure 7.4:	OHCAs (blue dots) and AEDs (red dots) in London	153
Figure 7.5:	OHCAs (blue dots) and AEDs (red dots) in East Midlands	154
Figure 7.6:	Proximity of OHCAs to public-access AEDs in London	155
Figure 7.7:	Proximity of OHCAs to public-access AEDs in East Midlands	156
Figure 7.8:	Real-world travel vs straight-line travel distance example	157
Figure 8.1:	The COM-B model, and how domains of the TDF integrate with it	169
Figure 9.1:	The Behaviour Change Wheel	204
Figure 10.1:	Straight-line (a, top) and real-world (b, bottom) travel distance	260
Figure 10.2:	ROC curves. Effect of GoodSAM response distance on alert acceptance (London)	261
Figure 10.3:	ROC curves. Effect of GoodSAM response distance on alert acceptance (East Midlands)	264

## LIST OF TABLES

<u>Table 3.1:</u>	<u>Data collected, with source, for work in chapter 6 and chapter 7</u>	<u>60</u>
<u>Table 3.2:</u>	<u>Data collected, with source, for work in chapter 10</u>	<u>68</u>
<u>Table 5.1:</u>	<u>Criteria for GoodSAM activation following potential OHCA</u>	<u>109</u>
<u>Table 6.1:</u>	<u>Description of GoodSAM alerts for OHCA</u>	<u>124</u>
<u>Table 6.2:</u>	<u>Patient and process variables by GoodSAM response group (London)</u>	<u>127</u>
<u>Table 6.3:</u>	<u>Patient and process variables by GoodSAM response group (East Midlands)</u>	<u>128</u>
<u>Table 6.4:</u>	<u>Patient outcome by GoodSAM response group (London)</u>	<u>129</u>
<u>Table 6.5:</u>	<u>Patient outcome by GoodSAM response group (East Midlands)</u>	<u>129</u>
<u>Table 6.6:</u>	<u>Characteristics of survivors and non-survivors from OHCA (London)</u>	<u>130</u>
<u>Table 6.7:</u>	<u>Multicollinearity table for independent variables included in the logistic regression model (London)</u>	<u>131</u>
<u>Table 6.8:</u>	<u>Logistic regression model. Adjusted odds ratios (AOR) for survival to hospital discharge (London)</u>	<u>132</u>
<u>Table 6.9:</u>	<u>Characteristics of survivors and non-survivors from OHCA (East Midlands)</u>	<u>133</u>
<u>Table 6.10:</u>	<u>Multicollinearity table for independent variables included in the logistic regression model (East Midlands)</u>	<u>134</u>
<u>Table 6.11:</u>	<u>Logistic regression model. Adjusted odds ratios (AOR) for survival to hospital discharge (East Midlands)</u>	<u>135</u>
<u>Table 7.1:</u>	<u>Proximity of OHCA to public-access AEDs</u>	<u>156</u>
<u>Table 8.1:</u>	<u>Barriers and facilitators to AED use by GoodSAM responders</u>	<u>177</u>
<u>Table 9.1:</u>	<u>Improving retrieval of a public-access AED – what needs to change?</u>	<u>219</u>
<u>Table 9.2:</u>	<u>Potential interventions for behaviour change: retrieval of a public-access AED en-route to a patient</u>	<u>234</u>
<u>Table 10.1:</u>	<u>GoodSAM alert outcome (London)</u>	<u>254</u>
<u>Table 10.2:</u>	<u>GoodSAM alert outcome by London Borough</u>	<u>255</u>
<u>Table 10.3:</u>	<u>Actions after alert acceptance (London)</u>	<u>257</u>
<u>Table 10.4:</u>	<u>Actions after alert acceptance, by time of day and time of week (London)</u>	<u>258</u>
<u>Table 10.5:</u>	<u>Alert outcome – current rules compared to historical radius (London)</u>	<u>262</u>
<u>Table 10.6:</u>	<u>OHCA process and outcome variables by GoodSAM alert status (London)</u>	<u>265</u>
<u>Table 10.7:</u>	<u>Logistic regression models: adjusted odds ratios (AOR) for survival to hospital discharge (London)</u>	<u>266</u>
<u>Table 10.8:</u>	<u>GoodSAM alert outcome (East Midlands)</u>	<u>269</u>
<u>Table 10.9:</u>	<u>GoodSAM alert outcome by East Midlands county or unitary authority</u>	<u>269</u>
<u>Table 10.10:</u>	<u>Actions after alert acceptance (East Midlands)</u>	<u>271</u>

<u>Table 10.11: Actions after alert acceptance, by time of day and time of week (East Midlands)</u>	<u>272</u>
<u>Table 10.12: OHCA process and outcome variables by GoodSAM alert status (East Midlands)</u>	<u>276</u>
<u>Table 10.13: Logistic regression models: adjusted odds ratios (AOR) for survival to hospital discharge (East Midlands)</u>	<u>277</u>
<u>Table 10.14: Alert status, before and after manual correction</u>	<u>279</u>

## **ABBREVIATIONS**

AED	Automated External Defibrillator
AMPDS	Advanced Medical Priority Dispatch System
AOR	Adjusted odds ratio
AUC	Area Under the Curve
BCW	Behaviour Change Wheel
BCTTv1	Behavioural Change Techniques Taxonomy version 1
BSREC	Biomedical and Scientific Research Ethics Committee
BHF	British Heart Foundation
CAG	Confidentiality Advisory Group
CAQDAS	Computer-Assisted Qualitative Data Analysis Software
COM-B	Capability, Opportunity and Motivation Behavioural Framework
95% CI	95% Confidence Interval
COSCA	Core Outcome Set for Cardiac Arrest
CPC	Cerebral Performance Category
CPR	Cardiopulmonary Resuscitation
CTU	Clinical Trials Unit
DA-CPR	Dispatch-Assisted Cardiopulmonary Resuscitation
ECI	Elixhauser Comorbidity Index (ECI)
EMAS	East Midlands Ambulance Service
EMS	Emergency Medical Service
EOC	Emergency Operations Centre
GCS	Glasgow Coma Scale
GIS	Geographical Information Systems
GPS	Global Positioning System
GRADE	Grading of Recommendations, Assessment, Development and Evaluation
HEMS	Helicopter Emergency Medical Service
HR	Hazard Ratio
ICU	Intensive Care Unit
ILCOR	International Liaison Committee on Resuscitation
IQR	Interquartile range
LAS	London Ambulance Service
MPDS	Medical Priority Dispatch System
MRC	Medical Research Council
mRS	Modified Rankin Scale

NHS	National Health Service
NICE	National Institute for Health and Care Excellence
NIHR	National Institute for Health Research
NPV	Negative Predictive Value
NNT	Number Needed to Treat
OHCA	Out-of-hospital Cardiac Arrest
OHCAO Registry	Out-of-hospital Cardiac Arrest Outcomes Registry
OR	Odds ratio
PAD	Public Access Defibrillation
PEA	Pulseless Electrical Activity
PPI	Patient and Public Involvement
PPV	Positive Predictive Value
PRISMA	Preferred reporting items for systematic reviews and meta-analyses
QALY	Quality Adjusted Life Year
RCT	Randomised Controlled Trial
ROBINS-I	Risk Of Bias In Non-randomised Studies - of Interventions
ROC	Resuscitation Outcomes Consortium
ROC curve	Receiver Operating Characteristic curve
ROSC	Return of Spontaneous Circulation
SAMBA Trial	Scandinavian AED and Mobile Bystander Activation Trial
SF-36	Short Form 36-item Questionnaire Health Survey
SOP	Standard Operating Procedure
SQPR	Standards for Reporting Qualitative Research
STROBE	Strengthening Reporting of Observational Studies in Epidemiology
TDF	Theoretical Domains Framework
UAV	Unmanned Aerial Vehicle
VIF	Variance Inflation Factor
VF	Ventricular Fibrillation
VT	Ventricular Tachycardia

## **ACKNOWLEDGEMENTS**

A big thank you goes to the following people:

My project supervisors: Professor Gavin Perkins, Professor Frances Griffiths and Professor Ranjit Lall.

Those that helped me get data and access to information. From the Out-of-Hospital Cardiac Arrest Outcomes registry: Scott Booth, Dr Terry Brown and Dr Chen Ji. From GoodSAM: Deepti Bal, Ali Ghorbangholi and Professor Mark Wilson. From London Ambulance Service: Dr Rachael Fothergill, Christopher Hartley-Sharpe and Jasmine Palmer. From East Midlands Ambulance Service: Robert Spaight and Neil White.

The research team at Copenhagen Emergency Medical Services, led by Professor Freddie Lippert, who hosted me on a training visit in February 2018.

The members of the Emergency, Prehospital, Perioperative and Critical Care (EPPiC) research team at Warwick Clinical Trials Unit, for feedback in meetings, offices and – most importantly – over coffee. In particular, Sam Brace-McDonnell, Dr Keith Couper, Dr Claire Hawkes, Helen Pocock, Dr Mike Smyth, Dr Joyce Yeung and the late Dr Carl McQueen.

Members of the project steering committee not already mentioned: Professor Ivo Vlaev, Professor Theo Arvanitis, Mr Julian Hague and Mr John Long.

Nicola Morrow and Zoe Evans at Warwick Clinical Trials Unit for administrative support.

My wife, Nicola, for putting up with me through the whole, um, adventure.

Rosemary (age 4) and Annabel (age 11 months) who provided distraction, sleepless nights and giggles. They *in no way* contributed to the completion of this thesis.

## DECLARATION

This thesis is submitted to the University of Warwick in support of my application for the degree of Doctor of Philosophy. I composed it and I have not submitted it in any previous application for any degree.

The work presented (including data generated and data analysis) was carried out by the author except in the following case:

- An initial review of the literature for a project not related to this PhD was performed in 2016. This subsequently formed the starting point for a formal scoping review in **chapter 4**. For the 2016 literature review I agreed key search terms in PubMed and Google Scholar and performed a title/abstract search with a second, independent author (S Lim Choi Keung). I have described this in **section 4.3.1** and this work also formed part of the published work 'Barriers and Facilitators to Public Access Defibrillation in Out-of-Hospital Cardiac Arrest – A Systematic Review', listed below.

Parts of this thesis have been published by the author:

### Peer-reviewed journal articles

1. **Smith CM**, Griffiths F, Fothergill RT, Vlaev I, Perkins GD. Identifying and overcoming barriers to Automated External Defibrillator use by GoodSAM volunteer first-responders in out-of-hospital cardiac arrest using the Theoretical Domains Framework and Behaviour Change Wheel. A qualitative study. *BMJ Open* 2020;10:e034908
2. **Smith CM**, Wilson MH, Ghorbangholi A, Hartley-Sharpe C, Gwinnutt C, Dicker B, Perkins GD. The Use of Trained Volunteers in the Response to Out-of-Hospital Cardiac Arrest – The GoodSAM Experience. *Resuscitation* 2017;121:123-6
3. **Smith CM**, Lim Choi Keung SN, Khan MO, Arvanitis TN, Fothergill F, Hartley-Sharpe C, Wilson MH, Perkins GD. Barriers and Facilitators to Public Access Defibrillation in Out-of-Hospital Cardiac Arrest – a Systematic Review. *Eur Heart J Qual Care Clin Outcomes* 2017;3:264-73

## **Conference abstracts**

*European Resuscitation Council Congress, September 2020 (virtual):*

1. **Smith CM**, Lall R, Fothergill RT, Spaight R, Perkins GD. An evaluation of the GoodSAM volunteer first-responder app for out-of-hospital cardiac arrest in two UK ambulance services. *Resuscitation* 2020;155(suppl):S2-3 **(oral presentation)**
2. **Smith CM**, Lall R, Fothergill RT, Spaight R, Perkins GD. The potential for bystander defibrillation for out-of-hospital cardiac arrest in two regions of the UK. *Resuscitation* 2020;155(suppl):S14 **(oral presentation)**

*European Resuscitation Council Congress, September 2018, Bologna, Italy:*

1. **Smith CM**, Lall R, Hartley-Sharpe C, Perkins GD. The potential for bystander automated external defibrillator deployment in London, UK. *Resuscitation* 2018;130(suppl):e43 **(poster presentation)**
2. **Smith CM**, Griffiths F, Hartley-Sharpe C, Fothergill R, Wilson MH, Perkins GD. Barriers to Automated External Defibrillation in a volunteer first-responder system. *Resuscitation* 2018;130(suppl):e137 **(poster presentation)**

For the parts of this thesis that have been published I performed data collection and analysis, synthesis of results and drafting of the manuscript or abstract and oral/poster presentation. The named co-authors reviewed and provided critique on the manuscript (or abstract and presentation), which I then appropriately revised. For the peer-reviewed journal articles further edits were made in response to peer-reviewer comments.

## **ABSTRACT**

**Introduction:** Bystander cardiopulmonary resuscitation (CPR) and Automated External Defibrillator (AED) use improve survival in out-of-hospital cardiac arrest. Volunteer first-responder systems may facilitate this. In the UK, the GoodSAM mobile-phone app alerts responders to a nearby patient if the ambulance service diagnoses cardiac arrest during a 999 call. In this PhD I investigate the effect of GoodSAM on out-of-hospital cardiac arrest outcomes and how to optimise public-access AED use during an alert.

**Methods:** I performed a scoping review into barriers and facilitators to public-access AED use; evaluated the impact of GoodSAM use on survival to hospital discharge; examined the potential for bystander public-access AED use; interviewed GoodSAM responders to identify barriers to public-access AED use during an alert; developed interventions to overcome these barriers using the Behaviour Change Wheel and; determined an optimum alerting distance for GoodSAM responders.

**Results:** GoodSAM alert acceptance was associated with improved survival to hospital discharge in London (2016–2017) – adjusted odds ratio 3.15, 95% confidence interval 1.19-8.36;p=0.021 – and East Midlands (2018) – adjusted odds ratio 3.19, 95% confidence interval 1.17-8.73;p=0.024. These findings could not be validated in 2019 datasets for either region. Few out-of-hospital cardiac arrests occur within 100m of a public-access AED, and calculating real-world travel routes substantially reduces this estimate. GoodSAM responders can use public-access AEDs but perceive a lack of opportunity to do so, and are concerned that delaying arrival at the patient would worsen outcome. Using the Behaviour Change Wheel, I proposed ten interventions to improve public-access AED use during a GoodSAM alert. Travel distance during an alert did not predict whether or not a GoodSAM responder reached the patient.

**Conclusion:** I did not find conclusive evidence of a benefit from GoodSAM in out-of-hospital cardiac arrest. We might improve public-access AED use during an alert by testing the interventions developed in this PhD.

# CHAPTER 1

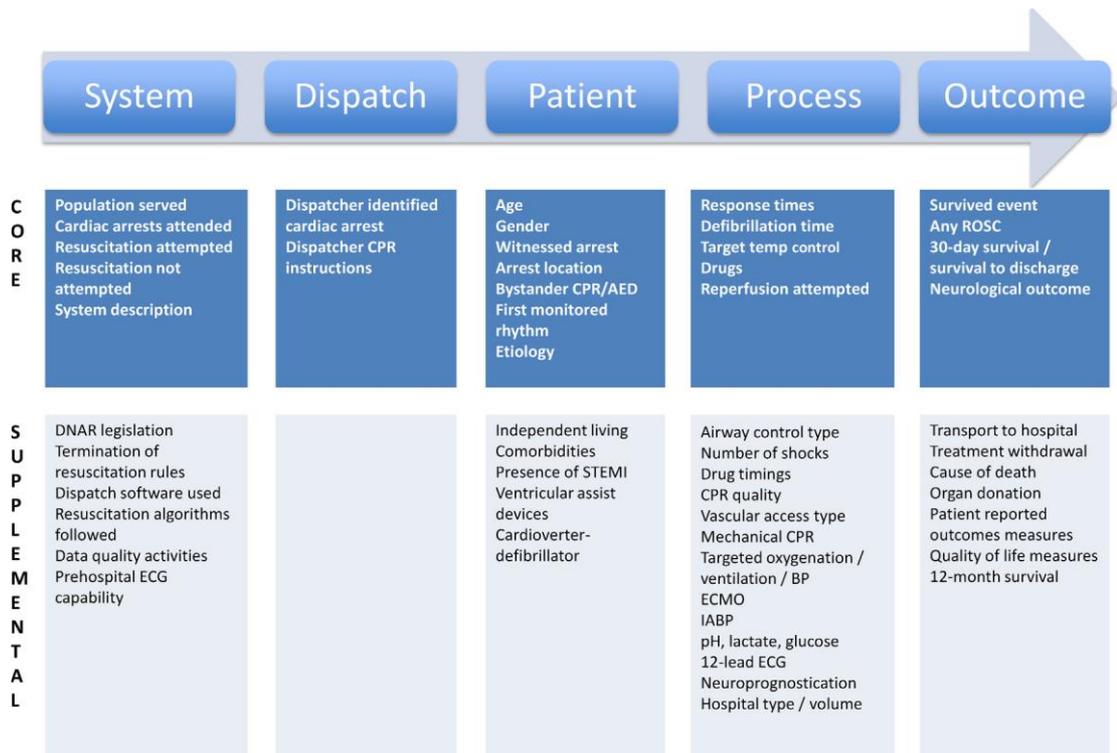
## The community response to cardiac arrest

Around one in ten people who sustain an out-of-hospital cardiac arrest (OHCA) survive to hospital discharge (1-5). Cardiopulmonary resuscitation (CPR) and defibrillation of the fibrillating heart are two efficacious means of improving survival (6). Both can be performed by bystanders before the arrival of the ambulance service. Developing and implementing strategies to improve bystander CPR and defibrillation using Automated External Defibrillators (AEDs) is crucial to maximise survival with good neurological outcome following OHCA.

### 1.1 **REPORTING OUT-OF-HOSPITAL CARDIAC ARREST**

There are a number of OHCA registries at national and regional level. Most of these registry data come from Europe, North America, Australasia and Asia (2,7), with a paucity of OHCA data from low- and middle-income countries (8). Most registries only report data about OHCA cases where the ambulance service either starts or continues CPR efforts. Some now report cases when bystanders performed defibrillation and the patient was no longer in cardiac arrest by the time the ambulance service arrived (7).

One should make direct comparisons between systems with caution: if criteria for starting resuscitation are more stringent, patients with a lower starting chance of survival would not be reported to a national registry, thus improving the reported survival *rate* in that registry. To that end, the Utstein template provides an international consensus for reporting OHCA. It recommends that registries collect and report a number of core and supplemental data sets across five domains (**Figure 1.1**) (9).



**Figure 1.1: The Utstein template: core and supplemental data. From Perkins et al (9), p331**

It suggests reporting for a number of subgroups, including a group of bystander-witnessed OHCA patients who received CPR and had a shockable rhythm, and for whom the ambulance service attempted resuscitation. This group (the ‘Utstein comparator group’) has perhaps the best survival potential of any OHCA patients, and can be used to *directly* compare the effectiveness of different systems (9). However, this may lead to an overestimation of the utility or cost-utility of interventions such as CPR or bystander AED use. At the time of a person’s collapse, one will not always know the cause and will never know the underlying heart rhythm for certain. A rescuer will not know whether an AED can help at the time they decide to use it.

The Utstein template records survival to hospital discharge or 30 days, and with favourable neurological outcome, using either the Cerebral Performance Category (CPC) (10) (1 or 2 on a scale of 1-5 represents a favourable outcome) or the modified Rankin Scale (mRS) (11) (0-3 on a scale of 0-6 represents favourable outcome) (9).

There are an estimated 60,000 OHCA in England each year. The Out-of-Hospital Cardiac Arrest Outcomes (OHCAO) registry at the University of Warwick reported on 30,829 cases in 2018 where the ambulance service attempted resuscitation. The registry includes all OHCA, in adults and children, regardless of cause. It reports outcomes including return of spontaneous circulation (ROSC) and survival to hospital discharge (12).

The Core Outcome Set for Cardiac Arrest (COSCA) project identified fifty-three potential outcome measures following a systematic review and interviews with OHCA survivors (and sometimes their partners), which were prioritised and taken forward for expert review. The authors recommended that researchers should report survival, neurological function and a health-related quality of life measure(s) – using a recognised tool for this – at hospital discharge or at 30-days post-event, and health-related quality of life measure(s) at 90-days, one year and at yearly intervals thereafter. Reporting these later outcomes has substantial resource implications, but they are important to OHCA survivors and their families (13).

## **1.2 EPIDEMIOLOGY**

The annual incidence of OHCA varies from around 19-113 per 100,000 people (1-3,6,12,14-16). The OHCAO registry reported an incidence of 54.7 per 100,000 in England (2018) (12). Slightly more men than women sustain OHCA and OHCA patients have a mean or median (variably reported) age in their mid-60s to early 70s (1,3,4,12,15,17-19).

Typically, around half of OHCA are witnessed by bystanders, (1,3,4,12,15,17,18). The majority of OHCA occur in residential rather than public locations (1,3,4,12,15,17,18). The proportion of patients who have a heart rhythm during OHCA that can appropriately be shocked with a defibrillator – i.e. ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT) – has been reported between 4.1-50% (1,2,4,6,12,15,17,18). In England (2018) the median age of OHCA patients was 70.8 years, and 65%

were male. The OHCA incidence was 77.3 per 100,000 in men and 35.0 per 100,000 in women. Bystanders witnessed 49% cases and 72% OHCA occurred in residential locations. At first cardiac rhythm analysis, 22% patients were in VF (12).

Longer-term trends have shown a decrease in the proportion of patients who had VF or VT when the heart rhythm was first recorded (2). The VF/VT rate will also be dependent on the time to first rhythm analysis, as VF/VT at the time of collapse will deteriorate over time into asystole (20). Bystander CPR can slow this rate of deterioration (20) and bystander AED use can shorten time to first shock (6): both will result in higher VF/VT rates at this earlier first rhythm analysis.

### **1.3 OUTCOMES**

#### **1.3.1 Survival**

A 2020 systematic review and meta-analysis reported that survival to hospital discharge following OHCA was 8.8% (from 103 studies) and one-month survival (from 33 studies) was 10.7% (5). Included studies had populations that reported at least 80% adult OHCA.

In England, survival to hospital discharge was 7.9% from 28,729 OHCA (OHCA) reported to the OHCAO registry in 2014 (1). This has increased year-on-year and was 9.3% from 30,829 cases in 2018 (12).

A report from national and regional registries in countries with membership of the International Liaison Committee on Resuscitation (ILCOR) reported survival to hospital discharge or 30 days between 3.1-20.4% and survival with favourable neurological outcome between 2.8-18.2% (either 2014 or 2015 data) (21). Differences in the make-up of the population, including age and co-morbid illness, may account for some of the variation, and so direct comparisons may not be meaningful. For example, in a 2010 systematic review of global OHCA the range of survival was 2% (Asia) to 11%

(Australasia), but incidence of VF similarly ranged from 11% (Asia) to 40% (Australasia) (2).

There can also be substantial variation within countries. The most recent English ambulance service data (February 2020) from NHS (National Health Service) England showed that survival to hospital discharge ranged from 3.2-12.5% across regional ambulance services (22), although these are crude figures not adjusted for age or other confounders. Data from the Resuscitation Outcomes Consortium (ROC) in the USA (May 2017–March 2018) reported that, for a randomly selected patient, the odds ratio (OR) for survival with good neurological outcome in the best performing area (compared to the worst performing) was 1.53 (95% confidence interval (CI) 1.37-1.78). This was in 43,656 adult OHCA, and *after* adjusting for patient- and systems factors thought to affect survival, suggesting there may often be confounders that we do not know about or appreciate fully (23).

Studying the Utstein comparator group (bystander witnessed, CPR performed, shockable rhythm, ambulance attempted resuscitation) may offer a better direct comparison between countries' performance. In 2018, survival to hospital discharge in England in the Utstein comparator group was 28.4% (12). This compares to internationally-reported figures of 28% from Asia (2009–2012) (4), 22% from Ireland (2012–13) (24), 33% from USA (2013) (15), 30% from Europe (27 countries, October 2014) (3), and 32% from NZ (2017–2018) (25).

### **1.3.2 Longer-term outcomes**

The 2020 systematic review and meta-analysis reported a one-year survival of 7.7% (from 22 studies) (5).

Many OHCA survivors have reasonably good longer-term outcomes. In the USA, 10.4% adults who sustained OHCA survived to hospital discharge in 2017, and 8.4% (or 81% of survivors) did so with a favourable neurological outcome (CPC 1-2) (26).

In Victoria, Australia (2000–2014), among 3,449 OHCA patients who survived to hospital discharge, the mean survival duration was 11.9 years (95% CI 11.7-12.1 years). Survivors were 5.6 times more likely to die than a standardised Australian population in the first year following their OHCA, but their risk was no higher than the general population by five years after OHCA survival. Those with better physical and functional outcomes were more likely to survive past one year (27).

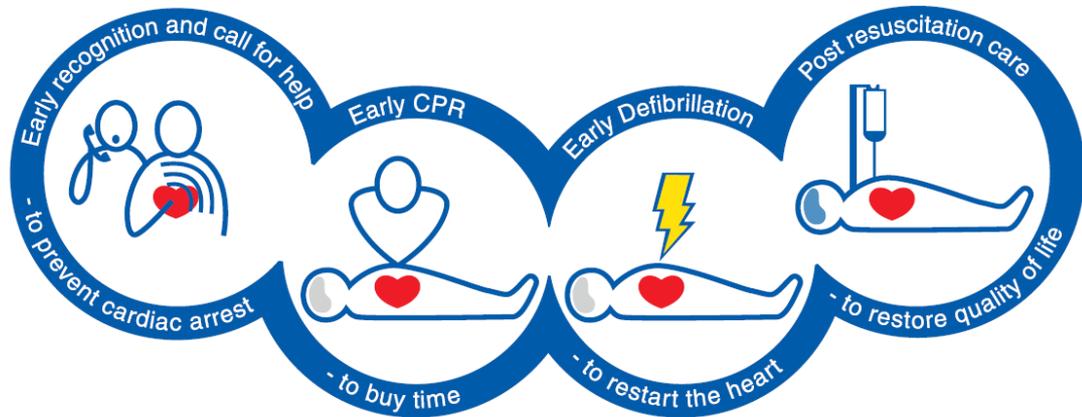
In 796 OHCA patients surviving to 30-days in Denmark (2001–2011), with a median age of 53, 77% returned to work. The median time to return to work was four months, and they spent a median of a further three years employed (28). A Finnish study of 206 OHCA survivors who were admitted to an Intensive Care Unit (ICU) reported that most were independent and 73% had returned to work by one year post OHCA (29).

A French registry study of 255 OHCA survivors in Paris (2000–2013) reported that OHCA survivors with CPC 1 had similar physical and mental health scores on the Short Form 36-item Questionnaire Health Survey (SF-36) – a measure of health-related quality of life – at a median of 50 months post-OHCA compared to controls. However, those with CPC 2 (which is also categorised by Utstein as a ‘favourable outcome’) and CPC 3 scored significantly worse (30). Ninety percent of OHCA survivors in the international Targeted Temperature Management Trial (who had to have a Glasgow Coma Scale (GCS) <8 at 20 minutes after ROSC, and were admitted to ICU) had physical and mental health scores on the SF-36 at approximately 180 days post-OHCA that were within the expected range for their age and sex (31).

#### **1.4 THE CHAIN OF SURVIVAL CONCEPT**

The Chain of Survival (**Figure 1.2**) is an internationally-recognised concept illustrating the actions or ‘links’ that need to be performed optimally in order to maximise the chance of survival following OHCA (6). The first three links concern actions that bystanders can perform before the arrival of a statutory

ambulance service response, even if they have no previous resuscitation training or experience.



**Figure 1.2: The Chain of Survival. From Perkins et al (6), p83**

The first link is early recognition of OHCA. Many ambulance service systems have scripted protocols during 999 calls to rapidly identify patients who are unconscious and not breathing normally. Adhering to these protocols improves OHCA recognition and increases dispatcher-assisted cardiopulmonary resuscitation (DA-CPR) rates (32).

The second and thirds links are early, high-quality CPR and early defibrillation. Survival is at least doubled if bystanders perform these actions (6). In England (2018) the median ambulance response time for OHCA calls was 6.9 minutes, and bystanders performed CPR in 69.5% and used an AED in 5.0% of OHCA not witnessed by the ambulance service (12).

In England, researchers developed a risk-prediction model for OHCA based on 2014 events in seven ambulance services regions, and then validated it on 2015 data. Age, gender, aetiology, a bystander witnessing the event, bystander CPR and initial cardiac rhythm formed an effective prediction model for survival to hospital discharge (33). A 2010 systematic review and meta-analysis of more than 142,000 OHCA patients across 79 studies (1984–2008) reported that bystanders or ambulance service witnessing the OHCA, bystander CPR, VF/VT as initial rhythm and ROSC pre-hospital increased

OHCA survival, with the biggest effects evident in systems where baseline survival was the lowest (34).

The best chance of improving survival for the largest number of people will be by focusing on those parts of the chain where we can make the most difference. In many systems, the ambulance service attempts resuscitation in approximately half of cases, and in around a quarter of these cases the patient will have a shockable rhythm at first cardiac rhythm analysis. It may seem that more may benefit from a focus on bystander CPR than on bystander AED use (35) but, because VF/VT rates decline over time (20), a higher proportion of patients will have a shockable rhythm if the first rhythm analysis is performed sooner by a bystander-attached AED.

## **1.5 THE ROLE OF THE AMBULANCE DISPATCHER**

### **1.5.1 Recognising out-of-hospital cardiac arrest**

Ambulance service dispatchers do not always recognise when a patient has sustained an OHCA during an emergency (999) call. In a 2018 systematic review of ambulance triage systems, sensitivity for diagnosing OHCA (the proportion of OHCA that the dispatcher correctly identified, true positives) ranged from 66-93% across five studies, and specificity (the proportion of non-OHCAs that the dispatcher correctly identified, true negatives) ranged from 32-99% in four studies (36). In two studies from this review (both in adults only), the positive predictive value (PPV, the number of dispatcher-identified OHCAs that actually had sustained OHCA) was 27% (37) and 67.4% (38), and the negative predictive value (NPV, the number of dispatcher-identified non-OHCAs that actually had not sustained OHCA) was 99.8% (37) and 31% (38). This means that not all OHCAs are identified, but also that a number of cases that are identified as OHCA subsequently are not.

In another systematic review (2017) of 15 observational studies, sensitivity ranged from 14-97% and PPV (six studies only) from 58-98%. These studies varied in the way that they identified OHCA (for example, electronic coding by

the dispatcher, researchers identifying key words on review of call transcripts, DA-CPR offered) and seven studies excluded children (under 18 years) (39).

These are a wide range of figures for sensitivity, specificity, PPV and NPV. This is potentially explained in part by differences in population and in the dispatch tools used, and is discussed below.

In England, four ambulance services use the NHS Pathways triage system and six currently use AMPDS (Advanced Medical Priority Dispatch System) (40). A study in Belfast (2008) of 158 OHCA reported a sensitivity for diagnosing OHCA of 69% and a PPV of 64% using AMPDS (41). Two studies from the South Central Ambulance Service in England examine OHCA recognition using the NHS Pathways triage system. In adults (16 years or older) during 2015-16, sensitivity was 76%, specificity 99%, PPV 27% and NPV 99.8%. There were 3,119 OHCA from 469,900 999 calls, of which 753 were cases where OHCA was not recognised during the 999 call. Extrapolating these data nationally would represent approximately 7500 unrecognised OHCA. However, a substantial number of cases identified as OHCA ultimately were not (37). In the same time period, sensitivity was 71%, specificity 96%, PPV 4% and NPV 99.9% for paediatric OHCA. There were 87 OHCA from 53,312 999 calls, of which 25 OHCA were not recognised during the 999 call. Only a very few children identified as having sustained an OHCA (4%, 87/2,052) ultimately had sustained one (42).

NHS Pathways systems identify OHCA if the answer to the questions (which are the first two asked during the 999 call) “*Is the patient conscious?*” and “*Is the patient breathing normally?*” are answered “*No*” (37). The presence of agonal (occasional, gasping) breaths, seen in approximately 40% of OHCA, decreases OHCA recognition during the emergency call (6), even though its presence may itself be associated with improved survival (6,43). In a study from Western Australia (2014–2015) of 176 OHCA, when asked if the patient was breathing, 113 bystanders answered “yes”. However, 50/113 of these answers were qualified with an explanatory statement about the quality, or normalcy of breathing (i.e. “yes, but...”). Many of these may represent agonal

breathing and dispatchers did not recognise OHCA during the emergency call in 32/50 (64%) of these calls (44).

In a study from Arizona, USA (2010–2014) of 2411 OHCA, the presence of agonal breathing reduced OHCA recognition during the emergency call from 93% to 79% and, when OHCA was recognised, increased time to recognition from 73.5 seconds to 118.5 seconds. The presence of agonal breathing was associated with increased survival to hospital discharge (adjusted OR (AOR) 1.63, 95% CI 1.17-2.25) and survival with a favourable neurological outcome (AOR 1.68, 95% CI 1.15-2.46) (43).

There are likely several other reasons why OHCA is not recognised. Bystanders are not always with the patient, and in a qualitative analysis of 13 OHCA calls in Copenhagen (2012), increased emotional distress was identified as a potential barrier to OHCA recognition (45). Contrastingly, in an audio analysis of 367 OHCA calls in Taiwan (2015–2016), OHCA was recognised sooner (median 29s vs 38s) when callers were rated 'uncooperative', using an 'Emotional Content and Cooperation Score'. The clinical relevance of this 9-second improvement is unlikely to be relevant, especially given that far fewer complied with dispatcher instructions to perform CPR due to their emotional state. (46).

Studies have reported that OHCA recognition during the emergency call improves survival to 30-days (47), hospital discharge (48) and at three months (49). Survival to hospital discharge (50) and survival with a favourable neurological outcome (50-52) is higher the sooner that recognition happens, although some of these studies were limited to adult OHCA (48,50-52).

### **1.5.2 Dispatcher-assisted CPR**

Internationally, current recommendations are that ambulance dispatch centres should have systems to allow the provision of DA-CPR instructions to bystanders managing adult OHCA patients (53,54), although fewer than half of ILCOR member countries had formal, nationwide DA-CPR protocols (55).

In the UK, the recommendation is that those taking 999 calls should ask if the patient is breathing “normally”, rather than just asking if they are breathing. There should be specific staff training to facilitate the identification of agonal breathing. Additionally, asking if the patient is a known epileptic might mitigate against unnecessary CPR, as seizure-like activity can occur at the onset of a cardiac arrest ([56,57](#)) and can inhibit OHCA recognition ([57](#)).

In a 2019 systematic review, in ambulance service systems who implemented DA-CPR protocols or where DA-CPR was variably offered, DA-CPR increased both survival to hospital discharge (AOR 1.33, 95% CI 1.07-1.66) and survival with a favourable neurological outcome (CPC 1-2) (AOR 1.47, 95% CI 1.03-2.09). There was no difference between DA-CPR and spontaneously initiated bystander CPR for either survival to hospital discharge (AOR 0.95, 95% CI 0.83-1.09) or survival with a favourable neurological outcome at hospital discharge (AOR 1.12, 95% CI 0.94-1.34) ([58](#)). Studies published since that systematic review have reported improved survival at 30 days ([59](#)) and with favourable neurological outcomes ([60,61](#)) following DA-CPR. In one study, those patients who received spontaneously initiated bystander CPR had better survival with favourable neurological outcomes than those whom received bystander CPR only after dispatcher instruction ([61](#)).

There is no clear evidence that DA-CPR improves CPR quality. Additionally, there is a gap in the literature about how to incorporate dispatcher instructions for retrieval and use of a public-access AED into existing protocols ([32](#)).

## **1.6 BYSTANDER CPR**

In England, bystanders performed CPR in 69% of non-ambulance-service-witnessed OHCAs in 2018, improving gradually year-on-year since 2014 ([12](#)). Bystander CPR rates ranged from 19-70% in registry data from ILCOR member countries (either 2014 or 2015 data) ([21](#)). A Europe-wide survey reported that bystanders initiated CPR in an average of 47% (range 6.3-78%) of OHCAs in 2014 (data from 27 countries) ([3](#)), and in an average of 58% (range 13-82%) of OHCAs in 2017 (data from 22 countries) ([14](#)). These figures

were 39% in the USA (2017) (26) and between 11-41% in seven Asian countries (2009–2012) (4).

Bystander CPR slows deterioration of VF/VT into a non-shockable heart rhythm (20,62,63) and increases survival (32). A 2018 systematic review and meta-analysis, including 19 studies and 232,703 patients reported an OR for survival after bystander CPR (compared to no bystander CPR) of 1.95 (95% CI 1.66-2.30). However, this effect may be limited to patients with a shockable initial cardiac rhythm (OR 2.10, 95% CI 1.68-2.63, based on six studies) rather than a non-shockable rhythm (OR 1.07, 95% CI 0.37-3.13, based on only two studies) (64). In an earlier systematic review (2010) the chance for survival to hospital discharge (bystander CPR vs no bystander CPR) was highest in systems with the lowest baseline survival (AOR 5.01, 95% CI 2.57-9.78) and lowest in systems with the highest baseline survival (AOR 1.23, 95% CI 0.71-2.11) (34).

Bystander CPR may also be associated with better long-term outcomes following OHCA. Among 2,281 30-day survivors from 25,505 adult OHCA in Denmark (2001–2014), bystander CPR was associated with a decreased chance of nursing home admission or brain damage at one year for both public (Hazard ratio, HR 0.55, 95% CI 0.36-0.84) and residential (HR 0.60, 95% CI 0.43-0.84) OHCA. However, it had no effect on all-cause mortality at one year (HR 1.13, 95% CI 0.60-2.12 for public and HR 0.78, 95% CI 0.52-1.17 for residential OHCA) (65). In King County, USA (2001–2010, 4448 OHCA aged 12 or older) the AOR (bystander CPR vs no bystander CPR) was 1.27 (95% CI 1.06-1.52) for survival to hospital discharge, 1.28 (95% CI 1.05-1.56) for survival to one year and 1.30 (95% CI 1.05-1.62) for survival to five years (66).

Increasing rates of bystander CPR might result in bystanders attempting to resuscitate a group of patients whom the ambulance service might otherwise have not resuscitated due to futility. So, counterintuitively, while the overall number of OHCA survivors in a system may go up, the survival *rate* may not: there will be a higher proportion of non-survivors in this group whose outcome we would not previously have reported (as CPR was not attempted).

## **1.7 BYSTANDER PUBLIC-ACCESS AED USE**

AEDs permit early defibrillation of an OHCA patient. Bystanders can safely use AEDs, even if they have minimal or no previous training (67). International guidelines also recommend that public-access AEDs can be used in children (6,68).

Public Access Defibrillation (PAD) – the use of public-access AEDs by bystanders before the arrival of the ambulance service – has been associated with an approximately doubling of survival to hospital discharge (OR 1.73, 95% CI 1.36-2.18) and survival with good neurological function (OR 2.12, 95% CI 1.36-3.29) (69).

Bystander public-access AED use may offer more of a survival benefit than bystander CPR (1,70), although high-quality data on this are lacking. I discuss the clinical effectiveness of PAD later in this chapter.

The COVID-19 pandemic has the potential to cause reductions in community intervention for OHCA. There is early published evidence (end of October 2020) from two systematic reviews that suggest bystander CPR rates have fallen in some systems and not others (71,72), and that bystander AED use (72) has fallen. This evidence is observational and limited, and the longer-term impact of COVID-19 on the community response to OHCA is uncertain.

## **1.8 OTHER FACTORS**

Studies have investigated other factors that might affect OHCA survival.

A 2019 systematic review of 29 observational studies reported that pre-OHCA co-morbidities were associated with lower rates of survival to hospital discharge and survival with favourable neurological outcome. However, there was great heterogeneity in how studies defined and reported co-morbidity, and so it is difficult to estimate risk from a particular co-morbidity or to quantify how

risk might increase if a patient has many different co-morbidities (73). Contrastingly, a review of more than 1.2 million OHCA in the USA (2006–2015) – published after this 2019 systematic review – reported that those with a higher comorbidity score (using the Elixhauser Comorbidity Index (ECI)) had higher survival to hospital discharge. Survival to hospital discharge over the study period increased in the group with ECI >3 and decreased in those with ECI 0. The reasons for this counterintuitive finding are not immediately clear, but it may be that the treatments used in those with co-morbidities confer a survival advantage (74).

Neighbourhood characteristics may predict rates of bystander intervention and OHCA survival (75). In Ireland (2012, 1,798 OHCA), bystander CPR, bystander public-access AED use and survival to hospital discharge were all significantly higher in urban areas than in rural areas (76). In the USA, studies have reported lower bystander CPR rates in predominantly black (77,78) and Hispanic (79) neighbourhoods, lower bystander public-access AED use in predominantly black (77) neighbourhoods, and lower survival to hospital discharge in predominantly black (77) and Hispanic (79) neighbourhoods (study authors' terminology in all cases). In England (2013–2015, 67,219 OHCA), neighbourhoods with more ethnic minorities, higher population density and fewer people in work had a higher incidence of OHCA and lower bystander CPR rates (80). Increased levels of social or economic deprivation were associated with lower survival in Toronto (2006–2014) (81).

A 2020 systematic review of 14 studies of adult OHCA concluded that being female was associated with higher mortality (i.e. lower survival to hospital discharge or 30 days) with an OR 1.56, 95% CI 1.32-1.84;  $p < 0.001$  (82). In a study from North Carolina (2010–2014, 8,100 OHCA), fewer women than men overall survived with a favourable neurological outcome, but once researchers adjusted for age, witnessed status and initial rhythm, survival chances were actually slightly higher in women. Increases in OHCA survival that were observed over time, however, were larger in men than in women (19). Female patients may be older, and they may receive bystander CPR, be

in VF/VT and sustain an OHCA in public less often. These are all possible reasons why (unadjusted) survival might be lower in women (83).

Survival in high-rise buildings has been independently associated with both floor of the OHCA (better survival on lower floors) (84), and with longer emergency response times (84,85): it is likely that these two factors are related. Better survival in specific facilities (such as airports (86), schools (87) and exercise facilities (88)) could be influenced by differences in age, co-morbidity, acute illness, aetiology, provision of bystander CPR and AED, and time of day.

The majority of information about factors affecting OHCA survival come from observational studies. There would now be a clear lack of equipoise for a Randomised Controlled Trial (RCT) into the effect of bystander CPR or bystander AED use on OHCA survival. Many of these observational studies attempt to make adjustments for known confounders affecting the variable of interest, but there may be confounders that are unknown and/or that interact with known confounders in unpredictable ways. It is unlikely that published observational studies will always appropriately account for all such confounders.

## **1.9 IMPROVING SURVIVAL**

### **1.9.1 Strategies to improve survival over time**

Comprehensive and integrated systems of care are required to improve OHCA outcomes (89). Interventions should be evidence-based (90), with measurement, feedback and public engagement essential to effective implementation (90-92). There are a number of published examples of such systems-based approaches.

Researchers in Minnesota reported on a comprehensive intervention package introduced there between 2006 and 2008 aimed at improving OHCA survival. Among the community-based interventions, they trained 28,000 people in

CPR/AED and added 132 additional public location AEDs. In a before-and-after comparison, bystander CPR (29% vs 20%) and survival to hospital discharge (19% vs 9% overall; 41% vs 17% for VF) were higher in 2009 than in 2005 (93).

The 'HeartRescue project', involving five geographically disparate sites and 41.1 million people in the USA, aimed to improve OHCA survival by 50% in its first five years. There were efforts to improve DA-CPR, bystander CPR rates and access to PAD (94). Between 2011 and 2015 bystander CPR increased from 42% to 44% (a clinically small but statistically significant difference,  $p < 0.001$ ) and bystander AED use increased from 3.2% to 5.6% ( $p < 0.001$ ). There was no improvement in overall survival to hospital discharge in the study period (95). There is not enough detail in the published results to be clear whether the interventions themselves were ineffective or just implemented poorly. It may be that it will take longer for survival benefits to be seen following implementation of the interventions.

In Denmark (2001–2010, 19,468 OHCA), 30-day survival increased from 3.5% to 10.8%, and both bystander CPR and bystander AED use were independently associated with this increased survival. Bystander CPR improved from 21.1% to 44.9% and bystander AED use from 1.1% to 2.2%. There were a number of public health initiatives during the study period including widespread CPR training and the expansion of PAD, which began in the last year of the study (96).

In Japan (2005–2014, 861,756 OHCA, excluding ambulance-service-witnessed cases) the AOR for survival with good neurological outcome in 2014 compared to 2005 was 2.81 (95% CI 2.57-3.07). Both bystander CPR and bystander AED use increased in the study period, and the authors associate bystander CPR with increased survival (without specifically commenting on its contribution to the AOR in the logistic regression model) (97).

In Singapore, researchers reported improved survival in a before-and-after study following implementation of widespread CPR training, increased public-

access AED placement, a DA-CPR programme and the use of volunteer first-responders alerted by mobile phone app. AOR for survival was 2.39 (95% CI 1.02-5.62) in the 'after' group (98) .

### **1.9.2 The UK perspective**

The Cardiovascular Disease Outcomes Strategy document, published by the Department of Health in 2013, outlined the aim to save 1000 additional lives per year. This would be achieved if survival to hospital discharge was increased from 7% to around 12% (99). Each of the home nations in the UK have strategies for improving OHCA outcomes (100-103), with common features including increasing numbers of people trained in CPR, and improving bystander CPR and AED rates. The Association of Ambulance Chief Executives and the National Ambulance Service Medical Directors similarly recognise the need for improvement in a number of areas, including: minimising the time to recognise OHCA, DA-CPR, and PAD schemes. PAD implementation should include means for ambulance dispatchers to know whether or not a particular AED is available at a certain time of day, and protocols to guide bystanders (where appropriate) to locate, retrieve and use a public-access AED (104).

In 2019, around 291,000 people received training in the UK on 'Restart a Heart Day' (105), which aims to train as many people with CPR/AED skills on or around October 16<sup>th</sup> each year (106). From September 2020, training in CPR will be part of the school curriculum in England and, although not central policy, all 32 local authorities in Scotland promised that every secondary school child would be trained in CPR. Wales and Northern Ireland have not yet made a specific commitment to CPR training in schools (107).

In England, the Department for Education and Department of Health provide schools with access to reduced-cost AEDs from the NHS Supply Chain. It is available to all schools, preschools, playgroups and sixth form colleges. Advice is also available on locating the device in a way that will make it accessible to the wider community (108).

The British Heart Foundation (BHF), in partnership with Microsoft, launched a UK-wide PAD database in June 2019 ('The Circuit'). This should allow ambulance services to better identify AEDs near to OHCA and, if possible, to direct bystanders to them. The expectation is that the database will capture details of public-access AEDs not already known to local ambulance services. There is the facility for AED owners to register their own device directly to the national database, or to continue to do so via their local ambulance service in many areas (109).

## **1.10 PUBLIC ACCESS DEFIBRILLATION**

Public Access Defibrillation (PAD) refers to the use of an AED for OHCA before the arrival of the ambulance service. This can include use by bystanders at the scene of an OHCA, by trained people available at a location with an AED and who have an expectation to respond (e.g. first aiders in a workplace or leisure facility), or by dispatched volunteer first-responders (110).

Registry data from ILCOR member countries show that PAD use occurs in between 2.0-37.4% of OHCA (either 2014 or 2015 data) (21). Other population-level studies have reported that PAD is generally used in no more than 5% of all OHCA (4,15,17,111). PAD occurred in only 2.4% OHCA in England, 2014 (1), increasing to 4.5% in 2018 (12). Even among the bystander-witnessed OHCA in England (2018) PAD occurred in only 6.7% OHCA (12), which represents a substantial missed opportunity to improve OHCA outcomes.

## **1.11 CLINICAL EFFECTIVENESS OF PAD**

### **1.11.1 Systematic review and meta-analysis findings**

A 2017 systematic review of articles published in any language compared the effect of bystander AED use to no bystander AED use on clinical outcomes for OHCA, in both adults and children (69). The review included three RCTs in the results (112-114). One (113) concerned home use of an AED for patients

with a previous anterior wall myocardial infarction, and another concerned professional fire and police first-responders with AEDs (112). Only one RCT (114) concerned public-access AED use by people in a bystander role before the arrival of an ambulance, and this is discussed further in **section 1.11.2**.

There were 44 observational studies in the systematic review (69). Of these, 34 had a 'critical' risk of bias, mostly because of confounding factors that had not been accounted for, when assessed using the ROBINS-I (Risk Of Bias In Non-randomised Studies – of Interventions) tool (115). The authors performed a meta-analysis on the remaining six studies (accounting for articles with overlapping data sets), totalling 77,956 OHCA patients (116-121). For all rhythms, the pooled OR was 1.73 (95% CI 1.36-2.18) for survival to hospital discharge or 30 days (three studies, 29,569 patients total) following bystander AED use, and 2.12 (95% CI 1.36-3.29) for survival with favourable neurological outcome (two studies, 12,333 patients). For shockable rhythms only, the pooled OR was 1.66 (95% CI 1.54-1.79) for survival to hospital discharge or 30 days (two studies, 46,032 patients), and 2.37 (95% CI 1.58-3.57) for survival with favourable neurological outcome (two studies, 46,117 patients) (69).

The studies represented OHCA in only four countries and were heterogeneously reported. Two excluded paediatric patients, three reported on OHCA of presumed cardiac aetiology only, one on public OHCA only, and one on witnessed OHCA only. This notwithstanding, the authors estimated a number needed to treat (NNT) of 10 to 30 for all rhythms, and 9 to 18 for shockable rhythms only, for one additional patient to survive to hospital discharge. The range in NNT depended on baseline survival rates, determined as 'low' (10%), 'medium' (20%) or 'high' (30%). Areas with the highest baseline survival showed the biggest absolute increase in survival and the lowest NNT – this probably reflects a patient population with a high pre-existing capacity to benefit (69).

It is not immediately clear why bystander AED use should improve clinical outcomes for all cardiac arrest rhythms, and not just the shockable ones. It

may be because of unrecognised confounders, or an underestimate of the interactions between bystander AED use and other factors – for example: location, witnessed status, gender, bystander CPR or other bystander actions. Even the six included studies had a ‘serious’ risk of bias (69). Researchers should treat evidence of effect, and the size of this effect, from observational studies with great caution.

A second systematic review in 2017 (122) looked at studies reporting on public-access AED use by non-dispatched bystanders (i.e. those already at or near the scene of an OHCA). The review included studies reporting when an AED was attached and/or when the AED delivered a shock. Where this distinction was unclear, the authors assumed that bystanders attached an AED but did *not* deliver a shock. They included only studies reporting on survival to hospital discharge, with or without a comparator group, using the Newcastle Ottawa Scale (123) to assess study quality. They excluded non-English studies and those reporting exclusively on those aged under 18 years old.

The authors identified 18 relevant studies. Ten of these 18 studies were from the USA. Survival to hospital discharge or at 30 days was 32% (range 14-78%) when bystanders attached an AED and, in cases where they could confirm that the AED had delivered a shock, 53% (range 26-72%) (122).

A concern with this analysis is that it may overestimate the utility of bystander AED at a population level. Few patients get to benefit from PAD, and it is likely that those who do are not comparable to the overall OHCA population. Bystanders who use AED may themselves be atypical. The fact that they have completed the potentially complex process of deciding to use, locating, retrieving and attaching an AED may identify them as bystanders who are more capable and more willing to perform well in an OHCA. In this review (122), where reported, all those who survived after bystander AED application did so with a CPC of 1-2, and the majority were CPC 1. This is a staggering finding, and we certainly need to compare this to better-quality evidence derived from RCTs.

### 1.11.2 Randomised Controlled Trials

The Public Access Defibrillation Trial (The PAD Trial) compared OHCA outcomes between areas with trained volunteers who provided CPR and used an AED, and areas with trained volunteers who provided CPR only. It ran in 24 regions across USA and Canada (2000–2003), and around 19,000 bystanders in 993 separate community sites participated. Researchers required that each site was capable of delivering an AED to the OHCA patient within three minutes of the collapse (114). There were significantly more trained volunteers ( $23 \pm 17.3$  vs  $17.6 \pm 15.3$ ) per site in the CPR/AED group, but patient and volunteer characteristics were otherwise similar.

Most (85%) study community sites were in public: mostly recreational or shopping facilities. Researchers included OHCA of presumed cardiac origin in patients aged 8 years or older in analyses. The study was powered at 80% to detect a 2.1-fold increase in survival to hospital discharge, assuming 7% baseline survival in the CPR-only group. In the CPR-AED group 23% (30/128) patients survived to hospital discharge, compared with 14% (15/107) in the CPR-only group ( $p=0.03$ , relative risk of survival 2.0, 95% CI 1.07-3.77). There was no difference in neurological outcome ( $p=0.90$ ), with 71% (CPR only) and 73% (CPR and AED) survivors having a 'normal' CPC score (defined as 'normal' 'mildly impaired' or 'moderately impaired' in this study). Bystander public-access AED use occurred for 34% OHCA in the CPR/AED group, but also for 1.9% OHCA in the CPR-only group (114).

This study remains the best-quality evidence available about bystander AED use. However, these results apply to the select population of patients who sustained a cardiac-origin OHCA in a public place, and had a response from a trained volunteer. It does not provide much information about the effectiveness of PAD in the population as a whole in these study areas – there would likely have been many OHCA patients for whom a response from volunteers registered with the study did not occur.

### 1.11.3 The UK perspective

The Resuscitation Council UK recommend bystander AED use in the UK (124). No training is necessary to use an AED. Those placing AEDs in public locations should consider the number and risk profile of people passing by it, and how large an area it can cover. The recommendation is that a bystander should be able to attach an AED to a patient within five minutes of their collapse (125). In areas such as transport hubs, sports or shopping facilities bystanders will witness a high proportion of OHCA and their response time with an AED should be short (126). However, there are no laws in the UK mandating placement of a public-access AED in any location (127).

Formal PAD programmes emerged in the UK in the 1990s, with public-access AEDs provided at high-risk locations, and community first-responders – specifically trained members of the public who were tasked to respond alongside the statutory ambulance service to certain incidents – equipped with AEDs. This scheme expanded nationwide and became the National Defibrillator Programme. In England and Wales (1999–2005) the National Defibrillator Programme recorded 1530 resuscitation efforts that included bystander AED use. Survival to hospital discharge was 9.5% (145/1530) overall: 18% (132/735) in those who received a shock before the ambulance service arrived and 1.6% (13/795) in those who did not. Bystander AED use was more successful than AED use by a community first-responder. Survival to hospital discharge was 26% (113/437) if a bystander attached an AED and 31% (106/347) if this AED delivered a shock. Survival to hospital discharge was 2.9% (32/1093) if a first-responder attached an AED and 3.8% (26/679) if this AED delivered a shock. Time to first CPR and first AED use were longer in OHCA first attended by community first-responders, which is a likely contributory factor to the observed differences (128).

The data from this study represented only OHCA for which an AED was deployed. What is not known is what proportion of the total number of OHCA that these cases represented, or how representative they were of the general

OHCA population. There was no logistic regression modelling to determine which factors were independently associated with survival.

The UK government provided a £1million investment to provide publicly available AEDs during 2015-16. The BHF administered this, and continue to offer PAD to organisations who can demonstrate a public need and who commit to allowing 24/7 access in an externally-located, unlocked cabinet (129). However, there are no data on the impact of this scheme on OHCA outcomes. The UK-wide PAD database, launched in June 2019, has been described in **section 1.9.2**.

#### **1.11.4 Other observational studies**

Much of the evidence about PAD, as already mentioned, comes from observational studies identified as very-low-quality evidence because of risks of bias, and inconsistent or imprecise results (32). The choice of comparator group in studies is important to avoid over-estimating the clinical benefit of PAD: it must be contemporaneous, and similar in terms of the factors known to impact on survival such as location type, witnessed status, bystander actions and initial cardiac rhythm. The circumstances of the OHCA in patients whom receive PAD may be more favourable than the general population. Patients with shockable rhythms are those that one would expect to benefit from early AED use. The cardiac rhythm cannot be known ahead of time, so the utility of bystander AED use should be considered and reported in the context of all OHCA. Otherwise, there is a risk of overestimating the utility of PAD.

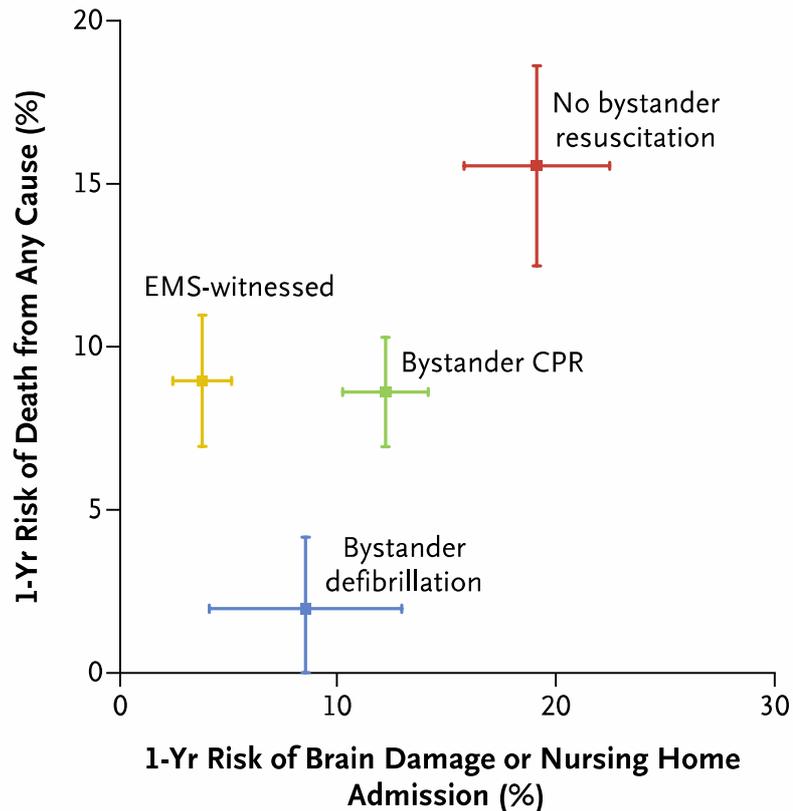
Improvements in survival have been reported in patients for whom an AED is attached but a shock is not delivered, so there are clearly unrecognised or under-appreciated confounders. Public-access AEDs are rarely placed completely at random, so there may be a bias towards survival based on the reasons that an organisation installs an AED at a particular site (130).

More recent studies (since the systematic reviews published in 2017) ([69,122](#)) have examined the association between bystander AED use and neurological outcomes. Reporting on 20,970 adult bystander-witnessed cardiac arrests with VF, the AOR for survival at one month with favourable neurological outcome following bystander AED use in Japan (2013–2015) was 2.33 (95% CI 2.05-2.66) ([131](#)). A related study in the same cohort reported that bystander AED use was associated with better survival with favourable neurological outcome for public location OHCA (52% vs 26%,  $p<0.001$ ) but not for residential location OHCA (23% vs 19%;  $p=0.357$ ) ([16](#)).

In a US study across nine regions (2011–2015, 2500 shockable rhythm OHCA) the AOR for survival with favourable neurological outcome was 2.73 (95% CI 2.17-3.44) in the 19% of patients who were defibrillated by a bystander using an AED ([132](#)). This is a select population, but it gives an indication of the size of the effect in the group of patients (shockable rhythms) who should gain most from early bystander AED use.

Two studies from Denmark examined the effect of bystander AED use on longer-term outcomes in OHCA survivors. In those surviving at least one day (2012–2014, 4641 presumed cardiac cause OHCA, aged 18 or older), ICU admission rates were lower in those receiving bystander CPR (AOR 0.94, 95% CI 0.91-0.97) and bystander AED (AOR 0.81, 95% CI 0.76-0.85). Overall hospital length of stay was also lower in those receiving bystander CPR (AOR 0.79, 95% CI 0.72-0.86) and bystander AED (AOR 0.68, 95% CI 0.59-0.78) ([133](#)).

Among 30-day survivors (2001–2012, 2855 OHCA patients aged 18 years or older) bystander public-access AED use (vs no bystander intervention) resulted in a lower risk of one-year death (adjusted HR 0.22 (95% CI 0.07-0.73);  $p=0.01$ ) and one-year nursing home admission or brain damage (adjusted HR 0.45 (95% CI 0.24-0.84);  $p=0.01$ ). This was greater than the effect of bystander CPR and is represented in **Figure 1.3** ([134](#)).



**Figure 1.3: Bystander interventions and one-year risk of death and brain damage/nursing home admission (Point estimates and 95% CI). From Kragholm et al (134), p1745**

A number of studies have demonstrated improved survival rates when a bystander attaches (118,128,135) or delivers a shock (136) using an on-site or nearby AED, compared to an AED brought to scene by a specifically trained/recruited first-responder. In these studies, there was little difference in survival between patients whose AED was attached by a first-responder and those who did not have an AED attached before the arrival of the ambulance service. Not all of these patients received a shock with the attached AED, so the time to all OHCA interventions rather than just time to first AED shock contributes to improved survival in these patients.

There is the potential for extremely high survival rates in specific patient groups. Survival of 71% was reported among 81 patients (from 2,858 cardiac-cause OHCAs in North Holland Province, Netherlands, 2006–2012) who were shocked by bystanders within two minutes of collapse (137). Researchers

have also reported high survival rates in specific locations such as airports (138-143), casinos (144,145) and schools (87). A Japanese study of 232 non-traumatic paediatric OHCA occurring in schools (2008–2015) reported that survival was significantly better if both CPR and AED were performed (AOR 4.08, 95% CI 1.25-13.31), but not with only CPR alone (AOR 1.06, 95% CI 0.23-4.88) or AED use alone (AOR 1.09, 95% CI 0.14-8.56) (146).

A small case series of 26 OHCA in 15 years (1999–2014) in sports centres in Piacenza, Italy reported survival with favourable neurological outcome in 93% of the 15 sites with an AED, and 9% in the 11 sites without (AOR 142, 95% CI 7.7-2520). Even allowing for the small sample and imprecision of the confidence interval, and any unrecognised differences between sites with and without AEDs, this is a stark difference (147). In Japan, researchers reported 28 cases of witnessed OHCA cases in road running races between 10km and marathon distance (42.2km) (2005–2017) when an AED was delivered by a support bicycle. A shock was delivered in 23 cases with a median time to first shock of 2.2 minutes. All 28 patients survived with favourable neurological outcome at both one month and one year (148).

### **1.12 COST-EFFECTIVENESS OF PAD**

Cost-effectiveness of a treatment is affected by the size of the intervention's effect on patient health outcomes. This concept is often represented by the Quality Adjusted Life Year (QALY) – representing years lived in perfect health, or equivalent, following an intervention. In the UK, the National Institute for Health and Care Excellence (NICE) does not formally identify a cost-per-QALY above which it deems that an intervention is not cost-effective. However, above £30,000 per QALY it becomes harder to make the case that the NHS should fund an intervention without compelling clinical reasons to do so (149).

The Holmberg 2017 systematic review (69) also identified ten studies concerning cost-effectiveness of bystander AED use. Seven of these reported that bystander AED use cost less than US \$100,000 per Quality Adjusted Life Year (QALY). However, individual studies were conducted in markedly

different settings, and there were major differences in estimates of AED usage rates and how effectively AED use would improve OHCA survival. Sometimes these estimates were made based on historical data from within that healthcare system or region, but this may reduce the generalisability of findings to other settings.

Additional assumptions, such as the proportion of VF/VT, time to delivery of first shock, baseline survival rates and downstream healthcare costs (e.g. hospital and ICU stays, rehabilitation) will also affect cost-effectiveness estimates. The upfront cost of AEDs is likely to come down over time. It is also likely that a substantial number of public-access AEDs are purchased and maintained by private individuals and organisations: in these cases, the capital costs are not met by the relevant health service.

The incidence of OHCA in an area is also a key variable in determining how cost-effective a scheme is likely to be (69), and strategic placement of AEDs based on OHCA incidence data will increase cost-effectiveness of PAD schemes (150). Cost-effectiveness improves further when AED usage rates increase, even when considering the downstream healthcare costs in survivors (151). Indiscriminately placing publicly accessible AEDs will save few extra lives (151) and will not be cost-effective (152-154).

Researchers estimated that a strategy of placing AEDs in all office buildings in Canada, irrespective of OHCA incidence, would cost \$511,766 (Canadian) per QALY (153). Moran et al examined the cost-effectiveness of various methods of placing PAD across Ireland in the wake of proposed legislation that would mandate AEDs in public places. The method initially proposed by the government of placing AEDs in 32 different types of public location would have required an additional 38,395 AEDs at an incremental cost-effectiveness ratio (supplementing AEDs that are already available) of 928,450 euros per QALY. The most scaled back version of the plan – including the placement of AEDs in transport stations, medical practices, entertainment venues, schools (excluding primary) and fitness facilities – required 1879 AEDs at a cost 95,640 euros per QALY. This assumed a PAD usage rate of up to 47% in public

locations, which is almost certainly too high. Subsequently the researchers recommended to the Irish government that any PAD scheme based on placing public-access AEDs by location type rather than OHCA incidence rate would not be cost-effective, and result in only 2-10 additional lives being saved each year (151).

Other PAD schemes are more cost-effective. In the PAD Trial, the additional cost-per-QALY in the CPR/AED arm was \$46,700 compared to the CPR-only arm (155). In North Holland, Netherlands (2005–2008), the total healthcare costs of OHCA *survivors* was estimated at 29,575 euros in patients for whom a bystander used an AED (n=136), 34,533 euros in patients for whom a first-responder used an AED (n=365), and 31,772 euros in patients for whom an AED was not used (n=1625). The reduced cost was mostly attributable to shorter ICU stays (135). In Copenhagen, the estimated cost (in 2005) of placing AEDs in high-risk areas for OHCA (defined as one OHCA every two or five years) was between US\$33,100 (one OHCA per two years) to US\$41,000 (one OHCA per five years) per QALY, compared to \$108,700 per QALY for random placement (156). A 2003 US study estimated the cost of placing AEDs in sites with an OHCA incidence of one every five years was \$30,000 per QALY: it assumed survival rates would be 2.5 times higher with AED use (157). In Scotland, researchers estimated a £41,146 cost per QALY for a strategy of placing AEDs in airports, railway stations and bus terminals, based on 38 OHCA occurring at 17 such sites (1991–1998). This figure assumed a 2% increase in survival to hospital discharge, but increasing the estimate to just a 2.5% increase in survival reduced costs to £32,225 per QALY. The baseline survival from these sites was, at 14.7%, higher than the population average (158).

### **1.13 FIRST-RESPONDERS FOR OHCA**

Community first-responders are locally organised groups staffed by volunteers who have received specific training and induction, who make themselves available to respond to OHCAs in their area. This voluntary response is in addition to but co-ordinated by the statutory ambulance service response in

that area, with the aim of reaching the patient and performing CPR and/or using an AED before the ambulance service arrives (159). In a European survey, two thirds of countries had community first-responder systems that were a mix of off-duty emergency service personnel or other volunteers (160).

A 2019 Cochrane Library systematic review investigated evidence from randomised trials about the effect of community first-responders in OHCA, compared to the standard ambulance service response alone (159). It identified one cluster RCT (Amsterdam, 2000–2002, 449 bystander-witnessed, non-traumatic adult OHCA cases where resuscitation was attempted) that randomised OHCA patients to either a supplementary response from trained police- and fire-service community first-responders with AEDs (n=243) or the statutory ambulance service response alone (n=226). Defibrillation occurred before ambulance service arrival in 15% (72/469) cases – all in the intervention group – but there was no difference in survival to hospital discharge (OR 1.3, 95% CI 0.8-2.2). Time to first shock was reduced from 12 min 49 secs (from first emergency call) to 11 min 8 seconds (p<0.001) (112). The long *absolute* time to first shock, despite the statistically significant reduction, may explain the lack of impact on survival.

A systematic review and meta-analysis of police first-responder schemes, with most published studies from North America, reported a pooled relative risk for survival of 1.6 (95% CI 1.3-1.6) compared with the standard ambulance service response alone. It comprised mostly observational studies, with heterogeneity in study results. The benefit of these schemes relied on factors such as the proportion of cases in which first-responders arrived before the ambulance service and the absolute reduction in arrival time compared to the ambulance service response alone (161).

#### **1.14 VOLUNTEER FIRST-RESPONDER SYSTEMS**

There are now a number of systems to alert volunteer first-responders to a nearby OHCA via their mobile phones. Volunteers must register with a system, and if notified they can offer assistance if they wish. They differ from traditional

community first-responders in a number of ways: there is no formal, standardised training, although many schemes will mandate a minimum level of training before allowing responders to register with their system; volunteers are responding as members of the public, even if they have healthcare experience; and there is no statutory obligation for them to respond.

#### **1.14.1 Systematic review**

The 2019 Cochrane Library systematic review ([159](#)) also identified one RCT about volunteer first-responder systems. In Stockholm (2012–2013, adults and children aged eight years and older, non-traumatic OHCA where resuscitation was attempted), researchers randomised individual OHCA patients to receive a supplementary response from volunteer first-responders within a 500m radius alerted via text message (n=306), or to receive the standard ambulance service response only (n=361). There were 9828 volunteers registered with the scheme, all with prior CPR training. There was no difference in 30-day survival (OR 1.34, 95% CI 0.79-2.29), although CPR was performed in significantly more cases before ambulance service arrival (62% vs 48%, OR 1.7, 95% CI 1.2-2.5) in the intervention group. Of note, the study was powered to detect a difference in CPR rates (its primary outcome) but not 30-day survival, and there was no mention of public-access AED use ([162](#)).

The Cochrane review concluded that the evidence for the survival outcome in this trial was low-certainty due to: exclusion of a high number of eligible participants (26%); ambulance service dispatchers not activating the alert system for all OHCA cases; and missing outcome data in 8.3% of patients ([159](#)).

#### **1.14.2 Observational studies**

There are a few observational studies that report patient outcome data after the use of mobile-phone-activated volunteer first-responders.

A retrospective analysis of 730 OHCA in the Gütersloh district of Germany (2013–2017), compared CPR initiated by either volunteers activated by mobile phone app (n=94), the ambulance service (n=359) or bystanders (n=277). The authors used propensity scoring to compare outcomes between the mobile-phone-activated group and the ambulance service (choosing 94 ambulance service cases best matched to the 94 mobile-phone-activated cases). In these adjusted analyses, survival to hospital discharge was higher in the phone-app group (OR 2.74, 1.08-6.96; p=0.049), with no difference in survival with good neurological outcome (OR 2.67, 0.80-8.86; p=0.165). There were no significant differences when mobile-phone-activated volunteers initiated CPR or when bystanders did. Overall, mobile-phone-activated volunteers arrived on scene in 342 cases (46%), and so these results (from 94 cases when they performed CPR) are highly selective and tell us little about the overall performance of that app-based system. There was also no record of who used an AED, so the authors could not account for this major confounder (163).

In Limburg, Netherlands (2012–2014, 833 OHCA of presumed cardiac origin where resuscitation was attempted) patients were more likely to survive to hospital discharge (AOR 2.8, 95% CI 1.52-5.24) if they were attended to by a volunteer first-responder, compared to those for whom an alerted rescuer did not attend. There were 422 text-message activations, resulting in at least one rescuer attending for 35% OHCA (291/833). Of these 291 cases, a lay rescuer was the first to start CPR for 25% (72/291) and connect an AED for 27% (78/291) (164). In a further analysis of all-cause OHCA from the same data source, the greater the number of volunteers as a proportion of total inhabitants in each of the 32 municipalities in the study area, the bigger the difference in survival when a volunteer arrived on scene compared to when they did not (165).

A before-and-after study reported on the effect of a bundle of interventions, including community CPR training, public-access AED installation and a text-message system alerting registered volunteers about a nearby OHCA and the location of the nearest AED. The authors compared 1498 OHCA in 2013–2015 with 1696 OHCA in 2015–2017. They reported increases in survival to hospital

discharge (13% vs 9.0%,  $p < 0.01$ ) and survival with favourable neurological outcome (8.3% vs 4.5%,  $p < 0.01$ ). It is not clear how big the influence of the text-message-alert volunteer system was on these improvements and how much might just reflect the maturation of the ambulance service and OHCA response systems over time (166).

### **1.15 OPTIMISING VOLUNTEER FIRST-RESPONDER SYSTEMS**

In 2015, ILCOR identified a lack of knowledge about how best to deploy public-access AEDs for OHCA, including the effect that volunteer first-responder systems may have on this (32). There is also a paucity of evidence in the published literature about how to optimise volunteer first-responder systems, and how to improve AED use in these systems.

Volunteer first-responders are not always activated in OHCA and they do not always respond (167), attend (164,167,168) or perform bystander CPR (167,169). There is infrequent use of public-access AEDs (168,170,171). In one survey of users of a text-message alert system in the USA, only 11% rescuers (135/1274) to whom activations were sent arrived on scene, and only eleven found a patient in cardiac arrest and initiated CPR (167).

There are a number of points to consider in overcoming these problems. Activations need to be sent, received and acted upon promptly, and newer app-based systems may result in a shorter time-to-arrival and more volunteer first-responders who arrive *first* on scene (172). App-based systems may require the ambulance service to decide whether to activate them (171,173), but can be automatically activated based on pre-determined criteria (167,174). Allowing ambulance service dispatchers the discretion to activate may reduce the number of inappropriate activations, but can delay dispatch when it is appropriate. Automatically activated systems will undoubtedly be faster, but the concern is that they might alert to more non-OHCA cases.

Volunteer first-responder activation radius differs between systems, with distances of up to 300m (174), 400m (167), 500m (162), 1km (164,168), 2.4km

(171) and 5km (175) reported in the literature. Some systems can alter the response radius according to perceived local need (167,174), and one system activated only those responders predicted to arrive before the ambulance service, based on average walking speed (173).

There is also little information about the link between travel distance and the likelihood of accepting an alert. Public-access AEDs are typically used in fewer than 5% of OHCA (111), but 6.6-25% of OHCA are located, in urban areas at least, within a 100m radius of an AED (176-181). However, retrieving an AED on the way to a patient as a volunteer first-responder may substantially increase travel distance. In one study, diverting via an AED increased median travel distance from 560m to 1280m (171). In another, the median travel *time* was significantly longer if the volunteer first-responder retrieved an AED first (median 275s via AED vs 197s direct to patient,  $p < 0.001$ ) (173).

It may also be important to understand exactly what interventions volunteer first-responders are providing when they reach a patient, how often they are performing them, and what the barriers to them doing this are. Knowledge about who is responding – for example, a number of volunteer first-responders may have previous healthcare experience (163,164) – may inform strategies to increase future recruitment.

At time of thesis submission, there is no published evidence about the effect of the COVID-19 pandemic on volunteer first-responder systems. Researchers and system operators should consider the potential effect on motivation to respond and plan future interventions to improve the system with that in mind.

### **1.16 VOLUNTEER FIRST-RESPONDERS – ONGOING RESEARCH**

There are two RCTs in progress. In the DISPATCH trial – a stepped-wedge, cluster RCT – researchers from France are investigating the effect of a “multifaceted intervention”, including dispatcher training in OHCA recognition, deployment of mobile-phone-activated volunteer first-responders, and weekly motivational feedback to those enrolled in the volunteer first-responder

scheme. The trial researchers will recruit adults (aged 18 years or older). The primary outcome is the initiation of CPR, with survival to hospital discharge and neurological outcomes among the secondary outcomes. The trial started recruiting in August 2018 and is due to complete in March 2021 ([182](#)).

The Scandinavian AED and Mobile Bystander Activation (SAMBA) Trial is an RCT currently recruiting in Copenhagen, Denmark, and in Stockholm County and the Västra Götaland Region, Sweden. It is randomising users of the Hearrunner volunteer first-responder app. In the control group, all responders will be instructed to go straight to the patient to start CPR. In the intervention group, a number of responders (if multiple responders are available) will be asked to retrieve an AED first. At least one responder in the intervention group will still go straight to the patient to perform CPR. The aim is to recruit 490 participants and the study is ongoing at time of thesis submission. The primary outcome is the proportion of patients with an AED attached before the ambulance service arrives, with 30-day survival and ROSC among the secondary outcomes ([183](#)).

### **1.17 CHAPTER CONCLUSION**

Fewer than one in ten people survive to hospital discharge following an OHCA. However, the majority who survive to hospital discharge will still be alive one year after the event, and many of these have good neurological or functional outcomes.

Community actions can improve survival. This includes interactions with ambulance service dispatchers to recognise cardiac arrest, performing CPR and using an AED. There may be other factors that affect OHCA survival, but it may not always be possible to identify or adjust for these in observational studies. It is likely that we require a number of different and linked interventions at local and population levels to meaningfully impact OHCA survival.

PAD is likely to result in better long-term survival with good neurological outcome, although the available evidence is generally of low quality. Targeted

PAD placement is needed for clinical and cost-effective AED use. Dispatching AEDs using traditional first-responders will not have much impact on survival, but there is hope for mobile-phone, app-based volunteer first-responder systems that could facilitate rapid CPR and AED use before the arrival of the ambulance service. There is much work to be done to evaluate and optimise these systems and the use of AEDs by volunteer first-responders.

# CHAPTER 2

## Thesis Aims and Objectives

## **2.1 INTRODUCTION**

A coordinated response between the statutory ambulance service and the community is vital to improve survival from out-of-hospital cardiac arrest (OHCA) (6). Bystander cardiopulmonary resuscitation (CPR) and public-access Automated External Defibrillator (AED) use result in substantial improvements in OHCA survival, even if ambulance service response times are short (1).

In 2015, the International Liaison Committee on Resuscitation (ILCOR) identified a lack of information about volunteer first-responder systems, and how these might support the use of public-access AEDs (32). Low rates of Public Access Defibrillation (PAD) in England (12) mean that there is huge potential to improve the use of public-access AEDs as part of a volunteer response.

Volunteer first-responder systems are proliferating and so will play an increasing role in the response to OHCA. The GoodSAM first-responder app, operating in many areas of the UK, is specifically mentioned in the 2019 National Health Service (NHS) Long Term Plan as a potential means to deliver CPR and bystander defibrillation to OHCA patients (p63) (184).

Prior to this PhD, there had been no published investigation into the impact of GoodSAM on OHCA outcomes, or about how to optimise its use.

## **2.2 AIM**

I aimed to investigate the effect of the GoodSAM first-responder app on OHCA outcomes, and how to overcome barriers to the use of public-access AEDs during a GoodSAM alert.

## 2.3 OBJECTIVES

In this PhD I have attempted to:

- Perform a structured review into barriers and facilitators to PAD. **Chapter 4**
- Characterise the current operation of the GoodSAM first-responder app. **Chapter 5**
- Investigate the effect of the GoodSAM first-responder app on survival to hospital discharge following OHCA in London and East Midlands. **Chapter 6**
- Investigate the potential for bystander AED use for OHCA patients in London and East Midlands. **Chapter 7**
- Identify barriers to AED use by GoodSAM first-responders when responding to a nearby OHCA. **Chapter 8**
- Develop evidence-based, theoretically-informed interventions that could increase AED use in GoodSAM first-responders when responding to a nearby OHCA. **Chapter 9**
- Further characterise the actions of GoodSAM responders during OHCA, and determine the optimum activation distance for GoodSAM responders. **Chapter 10**

# CHAPTER 3

## General methods

In this chapter I outline general methods for **chapters 4-10**. Where appropriate, I present more specific methodology in those chapters.

In this PhD I have used both quantitative and qualitative methodologies. Triangulating information gathered from different sources or using different methods increases the validity of data (185-187) and may lessen the risk that a researcher will try to fit data to match pre-conceived notions about what the answer should be (186). The project cannot truly be defined as ‘mixed methods’ research as the quantitative and qualitative elements are separate (188). These different elements *do* complement each other, and contribute to the overall aims of the project.

### **3.1 BARRIERS AND FACILITATORS TO PUBLIC ACCESS DEFIBRILLATION (CHAPTER 4)**

Part of the work in this chapter was published as a systematic review in October 2017 (111). I have detailed the methodology in **chapter 4**. I registered the review on the PROSPERO International Register of Systematic Reviews (University of York Centres for Review and Dissemination) on 18<sup>th</sup> February 2017: ([https://www.crd.york.ac.uk/prospero/display\\_record.php?ID=CRD42016035543](https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42016035543)).

### **3.2 A DESCRIPTION OF THE GOODSAM RESPONDER SYSTEM (CHAPTER 5)**

I produced this descriptive work and an associated peer-reviewed article published in December 2017 (174) using the following sources:

- Discussions with members of the project’s steering group from London Ambulance Service (LAS), East Midlands Ambulance Service (EMAS) and GoodSAM
- Standard Operating Procedure (SOP) documents from LAS and EMAS

- Information and associated documents available from GoodSAM and at <http://www.goodsamapp.org>
- Review of Key Informant interviews (from **chapter 8**)

### **3.3 GOODSAM EVALUATION AND AUTOMATED EXTERNAL DEFIBRILLATOR USE (CHAPTER 6 AND CHAPTER 7)**

I evaluated the effect of the GoodSAM responder system in LAS (April 2016 – March 2017) and EMAS (June 2017 – June 2018) on survival to hospital discharge from out-of-hospital cardiac arrest (OHCA). I mapped the locations of OHCA and public-access Automated External Defibrillators (AEDs) in both areas and determined the distance from each OHCA to its nearest AED.

#### **3.3.1 Ethical approval and data sharing**

The Biomedical & Scientific Research Ethics Committee (BSREC) at the University of Warwick granted ethical approval on 6<sup>th</sup> March 2018 (REGO-2018-2157) to analyse data from LAS. BSREC approved an amendment to add analysis of EMAS data on 29<sup>th</sup> October 2018 (REGO-2018-2157 AM01).

Ethical approvals were already in place allowing analysis of anonymised data from the OHCAO registry without further ethical review – Reference NRES 13/SC/0361; Confidentiality Advisory Group (CAG) (ECC 8- 04(C)/2013). Following my data sharing request, CAG deemed that all of the data fields I had requested (for work in **chapter 6 and 7**, and subsequently in **chapter 10**) were non-patient-identifiable.

For work in **chapter 6**, I signed a data sharing arrangement with the OHCAO registry for LAS data on 23<sup>rd</sup> April 2018 and for EMAS data on 6<sup>th</sup> February 2019. The University of Warwick (on my behalf) signed a data sharing arrangement with GoodSAM on 12<sup>th</sup> December 2017.

For work in **chapter 7**, the University of Warwick (on my behalf) signed a data sharing arrangement with LAS for a list of public-access AEDs registered with them on 13<sup>th</sup> December 2017. For EMAS, an individual unconnected with this project made a Freedom of Information request on 28<sup>th</sup> February 2019 for a list of locations for AEDs known to EMAS. EMAS subsequently made this list available online and I clarified its accuracy with them before using it.

### 3.3.2 Data collection

The OHCAO registry holds information from the majority of ambulance services in the UK about OHCA cases where the ambulance services attempted resuscitation. I have listed the data sources for **chapter 6** and **chapter 7** in **Table 3.1**.

**Table 3.1: Data collected, with source, for work in chapter 6 and chapter 7**

<b>System, dispatch, process and patient variables</b>			
<b>Variable</b>	<b>Format</b>	<b>Description</b>	<b>Data source</b>
OHCA cases	Number	Number of OHCA cases submitted by LAS and EMAS to the OHCAO registry in the respective study periods	OHCAO registry
GoodSAM activations	Number	Number of 999 calls when GoodSAM system activated. Not all will result in alert (if no responder in range). Not all will be confirmed OHCA	GoodSAM
GoodSAM alerts	Number	Number of GoodSAM alerts in respective study periods for LAS and EMAS regions. Not all alerts will be for OHCA	GoodSAM
OHCA cases for which there was a GoodSAM alert	Number; percentage	Number of confirmed OHCA cases for which there was a GoodSAM alert	OHCAO registry and GoodSAM
Date of ambulance call	dd/mm/yy	Date that the 999 call was made to LAS or EMAS	OHCAO registry
Time of ambulance call	hh:mm:ss	Time that the 999 call was made to LAS or EMAS	OHCAO registry

Date of GoodSAM alert	dd/mm/yy [blank if no alert]	Date that the GoodSAM alert was made. May be one, multiple or no alerts per OHCA event	GoodSAM
Time of GoodSAM alert	hh:mm:ss [blank if no alert]	Time that the GoodSAM alert was made. May be one, multiple or no alerts per OHCA event	GoodSAM
Outcome of GoodSAM alert	Accepted; Not seen; Rejected [blank if no alert]	The number of GoodSAM alerts that were accepted, declined or not responded to	GoodSAM
Time ambulance arrived at scene	hh:mm:ss	Recorded time that first ambulance personnel arrived at the OHCA location	OHCAO registry
Ambulance response time	hh:mm:ss	Calculated from the difference between 'Time ambulance arrived at scene' and 'Time of ambulance call'	Calculated value
Time GoodSAM responder arrived on scene	hh:mm:ss [blank if no alert]	Time that GoodSAM responder arrived on scene, if recorded	GoodSAM
OHCA location	Text	Location of OHCA event. Address and/or postcode from OHCAO registry for LAS data; descriptor (e.g. 'public', 'home') +/- postcode for EMAS; latitude / longitude for GoodSAM	OHCAO registry
AED location	Text	Location of public-access AEDs registered with LAS or EMAS. Provided as Eastings / Northings in both cases	LAS or EMAS
Patient age	Number; unknown	Patient age, in years	OHCAO registry
Patient gender	Male; Female; unknown	Patient gender	OHCAO registry
Bystander CPR performed	Yes; No; unknown	Did a bystander perform CPR before the arrival of the ambulance service?	OHCAO registry
Ambulance service witnessed status	Yes; No	Was the OHCA witnessed by the ambulance service? These	OHCAO registry

		cases are recorded as 'bystander CPR – no'	
AED used by member of the public	Yes; No; unknown	Was an AED used by a member of the public before the arrival of the ambulance service?	OHCAO registry
Initial cardiac arrest rhythm	VF/VT; asystole; PEA	First recorded cardiac arrest rhythm on arrival of the ambulance service	OHCAO registry

#### Outcome Variables

Variable	Format	Description	Data Source
Return of spontaneous circulation (ROSC)	Yes; No; unknown	ROSC at hospital following the OHCA	OHCAO registry
Survival to hospital discharge	Yes; No; unknown	Patient survived to hospital discharge; location of discharge not recorded	OHCAO registry

There is no unique identifying number allowing automatic matching of OHCA cases and GoodSAM alerts. Every time a 999 call-operator identified criteria during an emergency call that indicated a possible OHCA (defined by each ambulance service, described in **chapter 5**) the GoodSAM system automatically recorded this. If a GoodSAM responder was within a certain radius (again, defined by each ambulance service) GoodSAM sent out an alert. I manually matched date and time of the 999 call to the GoodSAM alert. I then confirmed that the location of the OHCA was the same from both data sources.

For LAS data I determined whether a location was residential or non-residential by review of the address description and postcode and, if necessary, accompanying images from the Street View function on Google Maps (<http://google.co.uk/maps>, Google LLC, California, USA). EMAS provided a location type (e.g. public, street, workplace, home) that I dichotomised.

LAS and EMAS both provided AED location as Eastings and Northings. I then converted OHCA location data from LAS and EMAS into Eastings and Northings using a freely available online Batch Geocoder (UK Grid Reference

Finder Batch Convert Tool: <https://gridreferencefinder.com/batchConvert/batchConvert.php>).

### **3.3.3 Data analysis**

I constructed logistic regression models to evaluate the effect of the GoodSAM first-responder app on survival to hospital discharge following OHCA, for both LAS and EMAS regions. Additionally, I provided summary statistics for other process variables. I discuss the variables included in the model, the statistical tests performed on the data and any assumptions about the data in detail in **chapter 6**. I performed statistical analyses using SPSS Statistics (version 26, IBM, New York, USA). I have explained this in more detail in **chapter 6**.

I used ArcGIS (version 10.5.1, ESRI, California, USA), a commercially-available Geographic Information Systems (GIS) software programme, to plot OHCA and AED locations on a map. I then determined the distance (both straight-line distance and real-world travel distance using roads and paths) from each OHCA to its nearest AED. I have explained this in more detail in **chapter 7**.

## **3.4 AN INVESTIGATION OF AED USE BY GOODSAM FIRST-RESPONDERS (CHAPTER 8 AND CHAPTER 9)**

This section describes methods for the work presented in **chapters 8 and 9**, and an associated peer-reviewed article published in February 2020 ([189](#)). I conducted interviews with GoodSAM first-responders in London who had recently received an alert about a nearby potential OHCA. The focus of interviews was the decision-making process concerning the use of a public-access AED during an alert. I also conducted interviews with 'Key Informants' involved in the integration of GoodSAM and LAS systems, to identify if there were any technical or organisational barriers that might influence public-access AED use.

I used the findings of the interviews to develop a list of potential interventions to increase public-access AED during a GoodSAM alert, using validated behavioural frameworks.

#### **3.4.1 Ethical approval**

The BSREC at the University of Warwick granted ethical approval on 16<sup>th</sup> March 2018 (REGO-2018-2164).

#### **3.4.2 Data collection**

I required permission to enter LAS premises to conduct Key Informant interviews (**chapter 8**). This was granted via letter on 20<sup>th</sup> April 2018.

I conducted face-to-face interviews with Key Informants in May 2018, and telephone interviews with GoodSAM responders in July and November 2018. I used Skype (audio only) to connect to the participants' preferred telephone number, allowing conversations to be recorded directly onto computer using QuickTime player.

I identified Key Informants with the assistance of LAS personnel on this project's steering group. I e-mailed Key Informants (e-mail content approved by BSREC), with participant information sheets and consent statements as attachments. They then replied to arrange a time and place for interview.

GoodSAM records details of its responders to whom an alert has been made. GoodSAM sent out e-mails (approved by BSREC) to GoodSAM responders who had received an alert in the prior seven days, with participant information sheets and consent statements as attachments. Participants arranged a time with me for interview, by e-mail return to my University e-mail address.

I created interview transcripts in Microsoft Word (Microsoft Corporation, Washington, USA) from the audio files, and these were later imported a Computer Assisted Qualitative Data Analysis Software (CAQDAS)

programme called NVivo (version 12, QSR International, Melbourne, Australia). I have detailed the interview and consent process for both GoodSAM responder and Key Informant interviews in **chapter 8**.

### **3.4.3 Data analysis**

Ontology is the study of reality, its nature and how this is affected by individual or societal actions. At its simplest, epistemology is how we learn about and gather knowledge about our reality (190). The qualitative approach is often considered ‘interpretivist’. Meaning is subjective and varies by person, place, time and environment. We gain knowledge – and can challenge basic assumptions – by exploring our actions, our natural environment and our place within it (191). These interactions may be complex and often unpredictable (192).

There was no pre-set hypothesis about what the barriers and facilitators to AED use in GoodSAM responders might be. The objective was to understand decision-making by individuals in an emergency situation, which would be influenced by how they understood their specific circumstances and interacted with the environment and people around them.

I performed a thematic content analysis of all interviews using the Framework Method (193), which itself is a type of Thematic Analysis (194). Source data are assigned a code from a pre-determined list, and similar codes are grouped into categories (or ‘themes’). The Framework Method is appropriate for use on data with a degree of homogeneity (194), and thematic analysis is appropriate for participants with a common experience (here, GoodSAM responders or the limited number of Key Informants) being interviewed about a specific topic (public-access AED use during a GoodSAM alert). The homogenous sample perhaps allows the researcher to build a more in-depth assessment of what the problems are and what the possible solutions may be (195).

The specific framework I used was the Theoretical Domains Framework (TDF) (196). In the TDF, codes are referred to as ‘constructs’ and the categories

within which they are grouped are called 'domains'. I uploaded the constructs and domains from the TDF into NVivo, and then associated these with relevant portions from interview transcripts.

I chose the TDF for a number of reasons. It is commonly used in the analysis of data from interview studies where behaviours are analysed (185), researchers have previously demonstrated that the TDF can be used to develop questionnaires (197) or a question/topic guide in interview studies (198), and it can be linked to the COM-B (Capability, Opportunity, Motivation, Behaviour) behavioural framework. Capability, opportunity and motivation are core targets for behavioural change that can inform the design of future healthcare interventions (198). COM-B itself can be directly linked to the Behaviour Change Wheel (BCW), which describes nine categories of intervention that address the core behaviours of the COM-B model, and seven policy categories that enable implementation of these interventions (199).

In **chapter 8**, I have conducted and analysed interviews using the TDF, and then grouped and presented findings according to COM-B. In **chapter 9**, I have integrated COM-B into the BCW – taking a stepwise approach suggested by the team who developed it (199) – to identify potential interventions to increase AED use by GoodSAM responders, and specific behavioural change techniques to support their implementation (200). The processes are detailed further in both chapters.

There are mixed results from behavioural change interventions, which may often be due to a poor understanding of the theory underlying them (201,202). The approach in this PhD is intended to be an integrated and robust method to synthesise new evidence and develop potential interventions that aligns with Medical Research Council (MRC) guidance on complex intervention development (203,204). It is the intention that one or more of the interventions will be implemented and evaluated in future work, but that was beyond the scope of this current PhD project.

### **3.5 DETERMINING THE OPTIMUM ACTIVATION DISTANCE FOR GOODSAM RESPONDERS NOTIFIED TO A NEARBY OUT-OF-HOSPITAL CARDIAC ARREST (CHAPTER 10)**

I conducted work to determine the optimum activation distance for a GoodSAM responder in LAS and EMAS regions, collecting data prospectively from September 2019 – March 2020.

At the time of this study, LAS activated responders up to a 700m radius away from the patient, and EMAS activated responders up to an 800m radius away. LAS previously used a 300m response radius (until 2018).

#### **3.5.1 Ethical approval and data sharing**

The BSREC at the University of Warwick granted ethical approval on 5<sup>th</sup> June 2019 (BSREC 50/18-19). I signed a data sharing arrangement for access to OHCAO registry data on 25<sup>th</sup> June 2019. The University of Warwick (on my behalf) signed a data sharing arrangement with GoodSAM on 16<sup>th</sup> July 2019.

#### **3.5.2 Data collection**

I conducted a cross-sectional study examining the response to all GoodSAM alerts sent to responders (September 2019 – March 2020) in London and East Midlands. In region I attempted to determine, for all GoodSAM alerts: the proportion of GoodSAM alerts that resulted in a responder reaching the patient's side before the arrival of the ambulance service and; an optimum response distance threshold for GoodSAM alerts. For confirmed OHCA cases only (September – December 2019) I determined the effect that a) accepting a GoodSAM alert and b) arriving at the patient's side made to survival to hospital discharge.

I gathered data from GoodSAM and the OHCAO registry. I gathered some information directly from GoodSAM responders themselves in a Survey Monkey (SVMK Inc., California, USA) questionnaire. GoodSAM sent

responders a link via e-mail to this questionnaire following the conclusion of an alert. This questionnaire was developed specifically for the study period and formed part of the BSREC ethics application. GoodSAM already recorded some information in a (voluntary) in-app post-event feedback form, and they made this information available to me as well. I have provided more details about the questionnaire and in-app post-event feedback in **chapter 10**.

I used ArcGIS to plot patient- and GoodSAM responder locations on a map. I then determined the distance between each GoodSAM responder and the relevant incident to which they had been alerted. I have explained this in more detail in **chapter 10**.

I have listed the data sources for **chapter 10** in **Table 3.2**.

**Table 3.2: Data collected, with source, for work in chapter 10**

<b>System, dispatch, process and patient variables</b>			
<b>Variable</b>	<b>Format</b>	<b>Description</b>	<b>Data source</b>
OHCA cases	Number	Number of OHCA cases submitted by LAS and EMAS to the OHCAO registry in respective study periods	OHCAO registry
GoodSAM activations	Number	Number of 999 calls when GoodSAM system activated. Not all will result in alert (if no responder in range). Not all will be confirmed OHCA	GoodSAM
GoodSAM alerts	Number	Number of GoodSAM alerts in respective study periods for LAS and EMAS regions. Not all alerts will be for OHCA	GoodSAM
OHCA cases for which there was a GoodSAM alert	Number; percentage	Number of confirmed OHCA cases for which there was a GoodSAM alert	OHCAO registry and GoodSAM
Date of ambulance call	dd/mm/yy	Date that the 999 call was made to LAS or EMAS	OHCAO registry
Time of ambulance call	hh:mm:ss	Time that the 999 call was made to LAS or EMAS	OHCAO registry

Date of GoodSAM alert	dd/mm/yy [blank if no alert]	Date that the GoodSAM alert was made. May be one, multiple or no alerts per OHCA event	GoodSAM
Time of GoodSAM alert	hh:mm:ss [blank if no alert]	Time that the GoodSAM alert was made. May be one, multiple or no alerts per OHCA event	GoodSAM
Outcome of GoodSAM alert	[blank if no alert]	The number of GoodSAM alerts that were accepted, declined or not responded to	GoodSAM
GoodSAM responder arrives on scene	Yes; no	From questionnaire sent to GoodSAM responders who accept an alert; cross-referenced with GoodSAM's own records	GoodSAM
Travel modality to scene	foot; bicycle; motorised vehicle; other	From questionnaire. How did the GoodSAM responder get to scene?	GoodSAM
Patient suffering OHCA	yes; no; N/A (did not reach scene)	From questionnaire. Was the patient suffering an OHCA?	GoodSAM
Assistance provided by GoodSAM responder	CPR; AED use; other; N/A	From questionnaire. What did the GoodSAM responder do once they were on scene	GoodSAM
Time ambulance arrived at scene	hh:mm:ss	Recorded time that first ambulance personnel arrived at the OHCA location	OHCAO registry
Ambulance response time	hh:mm:ss	Calculated from the difference between 'Time ambulance arrived at scene' and 'Time of ambulance call'	Calculated value
Time GoodSAM responder arrived on scene	hh:mm:ss [blank if no alert]	Time that GoodSAM responder arrived on scene, if recorded	GoodSAM
OHCA location	Text	Location of OHCA event. Address and/or postcode from OHCAO registry for LAS data; descriptor (e.g. 'public', 'home') +/- postcode for EMAS; latitude / longitude for GoodSAM	OHCAO registry
OHCA location area	Text	In which borough (London) or constituency (East Midlands) did the OHCA occur	Calculated value

Patient age	Number; unknown	Patient age, in years	OHCAO registry
Patient gender	Male; Female; unknown	Patient gender	OHCAO registry
Bystander CPR performed	Yes; No; unknown	Did a bystander perform CPR before the arrival of the ambulance service?	OHCAO registry
Ambulance service witnessed status	Yes; No	Was the OHCA witnessed by the ambulance service. These cases are recorded as 'bystander CPR – No'	OHCAO registry
AED use by member of the public	Yes; No; unknown	Was a 'Public Access Defibrillator' used by a member of the public before the arrival of the ambulance service?	OHCAO registry
Initial cardiac arrest rhythm	VF/VT; asystole; PEA	First recorded cardiac arrest rhythm on arrival of the ambulance service	OHCAO registry
GoodSAM responder location	Text	Latitude and longitude of GoodSAM responder at time of alert	GoodSAM
Travel distance to OHCA	Text	Calculated distance using OHCA location and GoodSAM responder location	Calculated value

#### **Outcome Variables**

<b>Variable</b>	<b>Format</b>	<b>Description</b>	<b>Data Source</b>
GoodSAM responder reaches patient side	Yes – before ambulance; yes – after ambulance; no	From questionnaire	GoodSAM
Survival to hospital discharge	Yes; No; unknown	Patient survived to hospital discharge; location of discharge not recorded	OHCAO registry

There was additional programming required in order for GoodSAM to extract responder location at the time of an alert, which I required to calculate travel distance. The University of Warwick (on my behalf) signed a subcontract with GoodSAM for these programming costs (£20,000) on 18<sup>th</sup> August 2019. The required money was part of my funding award from the National Institute of

Health Research (NIHR) for my Doctoral Research Fellowship (see **section 3.7.4**)

### **3.5.3 Data analysis**

For each ambulance service region, I have provided point estimates (with 95% confidence intervals) for the proportion of GoodSAM responders that reach the patient before the ambulance service following an alert for a potential OHCA. For LAS only – where the current response radius is 700m – I have compared this proportion with the number that would have reached the patient before the ambulance service had LAS still been operating their previous 300m response radius.

I have created Receiver Operating Characteristic (ROC) curves to determine the optimum threshold for GoodSAM responder travel distance, when considering whether or not they reached the scene before the ambulance service. Additionally, I have stratified this by borough (in London) or county/unitary authority (in East Midlands) and reported any differences in this threshold. I used ArcGIS to upload files containing boundary information for these areas; the programme then associated OHCA's occurring within a borough or county/unitary authority with that area. I have provided further detail in **chapter 10**.

For confirmed OHCA cases, I have constructed multiple logistic regression models for each ambulance service region to determine whether or not a GoodSAM responder a) accepting an alert or b) reaching the patient before the ambulance service is associated with survival to hospital discharge when adjusted for other confounders.

## **3.6 DATA STORAGE**

All electronic data files created during this PhD were stored either on a desktop computer in Warwick Clinical Trials Unit (CTU) or on a University-managed laptop. Both use Windows 10 requiring dedicated log-in to access unencrypted

contents: otherwise all work on those computers was encrypted. Additionally, each individual data file was password-protected. I kept copies of data files on the University secure data servers, and these files were password-protected and separately encrypted using PGP encryption software (version 10.4, Symantec, Arizona, USA).

### **3.6.1 Written data**

The OHCAO registry at the University of Warwick made data available by granting me access to a secure shared folder on the University servers within which the data files were held. I transferred these source data into an encrypted folder to which only I had access.

GoodSAM, LAS and EMAS transferred files to my University e-mail address. I saved these data into an encrypted folder to which only I had access and deleted source e-mails and attachments.

All source written data (from GoodSAM, the OHCAO registry, LAS and EMAS) and electronic data collection forms created – using Microsoft Excel (Microsoft Corporation, Washington, USA) – from this data are accessible only from the study computer at Warwick CTU or the University-managed laptop, both requiring dedicated log-in.

### **3.6.2 Visual and mapping data**

The ArcGIS programme sits on the hard drive of the study computer at Warwick CTU. The source location for files with OHCA and AED location data (which ArcGIS accesses when producing maps and visual information) are encrypted and password-protected as described above.

Where I have presented visual mapping data in the results I have done so at a scale and level of detail that precludes identification of an individual location. The maps displayed are available under the ‘Open Data’ licence from Ordnance Survey, which are covered by the Open Government Licence:

<http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/>.

This allows for the copying and distribution of the data. The required acknowledgements are displayed in full at the start of **chapter 7** and **chapter 10**.

### **3.6.3 Interviews**

I created a consent statement, participant information sheet, interview schedule and interview topic guide for both GoodSAM responder interviews and Key Informant interviews. These were all submitted to BSREC as part of the ethical approval process for this part of the project. I produced printed consent forms for the face-to-face Key Informant interviews. Once an interview had been completed, I scanned and stored these within 24 hours as an encrypted and password-protected file and shredded the originals.

Once a participant had completed their interview, I exported e-mail correspondence with them into a Microsoft Excel (Microsoft Corporation, Washington, USA) file, and deleted the original e-mails. I stored audio recordings and subsequent transcripts of GoodSAM responder interviews directly on computer. I kept e-mail data, audio files, original transcripts, and the NVivo file containing interview transcripts in separate folders. All data was encrypted and password-protected as described above.

I adopted a common naming format ('Participant initials – interview #' e.g. 'CS – 01') for interviews. This naming format reflects the order in which I conducted interviews, and would allow me to match audio recordings with transcripts and/or with the original participant, should the need ever arise.

### **3.6.4 Archiving**

I will keep all documentation from this PhD, and any associated peer-reviewed publications, at Warwick CTU for at least ten years after completion of the PhD or any publication that is based on this study data, in accordance with University of Warwick's Research Data Management Policy:

[https://warwick.ac.uk/services/ris/research\\_integrity/code\\_of\\_practice\\_and\\_policies/research\\_code\\_of\\_practice/datacollection\\_retention/research\\_data\\_mgmt\\_policy](https://warwick.ac.uk/services/ris/research_integrity/code_of_practice_and_policies/research_code_of_practice/datacollection_retention/research_data_mgmt_policy)

A copy of all project data will be stored in encrypted folders on the secure file server at the University of Warwick and available to me if needed in the future.

I will be responsible for secure deletion of data, and will seek advice from the University's Information Technology Services team at the relevant time.

### **3.7 STUDY OVERSIGHT**

#### **3.7.1 Supervisors**

##### Primary supervisor

- Professor Gavin Perkins (Warwick CTU)

##### Secondary supervisors

- Professor Frances Griffiths (Warwick Medical School, Division of Health Sciences, qualitative researcher)
- Professor Ranjit Lall (Warwick CTU, statistician)

#### **3.7.2 Steering committee**

Steering group membership:

- Professor Mark Wilson (GoodSAM medical director and co-founder)
- Dr. Rachael Fothergill (London Ambulance Service)
- Mr. Christopher Hartley-Sharpe (London Ambulance Service)
- Mr. Robert Spaight (East Midlands Ambulance Service)
- Dr. Claire Hawkes (Senior Research Fellow, Warwick CTU)

- Professor Ivo Vlaev (Warwick University Business School, Behavioural Science department)
- Professor Theo Arvanitis (Warwick University Institute of Digital Healthcare)
- Professor Freddy Lippert (University of Copenhagen & Copenhagen Emergency Medical Services)
- Mr. Julian Hague (PPI)
- Mr. John Long (PPI)

LAS, EMAS and GoodSAM all had representatives in this steering group who provided input into study design and protocols, and helped ensure access to relevant datasets, responders and ambulance service personnel. None of the data sharing arrangements or subcontracts entered into by the University of Warwick (on my behalf) and these partner organisations allow them to block dissemination or peer-reviewed publication of the findings from this PhD without reasonable justification.

Both Dr. Hawkes and Professor Vlaev have experience in the use of behavioural frameworks and the use of policy to change behaviours. Professor Theo Arvanitis is Head of Research at the Institute of Digital Healthcare at the University of Warwick and can offer important advice about the technical aspects of any intervention developed.

Professor Lippert has an established track record of impactful research about Public Access Defibrillation. During the course of this PhD, he and his research team shared information about Public Access Defibrillation and volunteer first-responder systems in Copenhagen to further my understanding of such systems.

### **3.7.3 Patient and Public Involvement**

Mr. Hague and Mr. Long are Patient and Public Involvement (PPI) representatives. They agreed to participate because of their previous interest

in cardiac arrest research. They contributed to study design and protocols for the work in **chapters 6 to 10**. In particular, they advised on the participant information and conduct of interviews for the work in **chapter 8**, including:

- The optimal way to ask GoodSAM responders to participate in interviews. Many responders have not had formal medical training, and all may have experienced difficulties when responding to an OHCA in a 'Good Samaritan' capacity
- The content and language used in participant information sheets and consent forms
- Development of interview topic guides

In addition, to obtain a broader perspective of public views, an outline of the study research plan was presented to the Clinical Research Ambassador Group – a regional public-involvement group hosted by University Hospitals Birmingham NHS Foundation Trust – in December 2016, at the start of this PhD. This is a PPI group open to all patients and carers in the area that the trust covers, and has meetings where representatives can advise on study design.

#### **3.7.4 Funding**

I began this PhD on a part-time self-funded basis on 1<sup>st</sup> November 2016. I was subsequently awarded an NIHR Doctoral Research Fellowship (DRF-2017-10-095) and was funded by the NIHR on a full-time basis between 1<sup>st</sup> November 2017 and 31<sup>st</sup> October 2020. The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR or the Department of Health and Social Care.

### **3.8 REPORTING RESULTS**

I reported the systematic review (**chapter 4** and associated publication) taking account of PRISMA (Preferred Reporting Items for Systematic reviews and

Meta-Analyses) Systematic Review checklist (205), the observational data (**chapters 6 and 7; chapter 10**) according to the STROBE (Strengthening Reporting of Observational Studies in Epidemiology) guidelines (206), and qualitative data (**chapters 8 and 9** and associated publication) according to the SRQR (Standards for Reporting Qualitative Research) guidelines (207).

I present OHCA data (from relevant chapters) taking account of Utstein guidelines – an internationally recognised and standardised methodology for reporting OHCA that records 23 core elements across five domains (system, dispatch, patient, process, outcome) (9).

# CHAPTER 4

## Barriers and facilitators to Public Access Defibrillation in out-of-hospital cardiac arrest

---

**Part of this chapter has already been published (111):**

**Smith CM**, Lim Choi Keung SN, Khan MO et al. Barriers and facilitators to public access defibrillation in out-of-hospital cardiac arrest: a systematic review. *Eur Heart J Qual Care Clin Outcomes* 2017;3:264-73

---

#### **4.1 INTRODUCTION**

Survival to hospital discharge worldwide following out-of-hospital cardiac arrest (OHCA) is generally around 10% (5), but this can be much higher in select groups. Survival rates as high as 70% have been reported in patients with cardiac-cause OHCA who were defibrillated within two minutes of their initial collapse (137).

Automated External Defibrillators (AEDs) can be used safely and effectively by members of the public, even if they have received no prior training (67). Public Access Defibrillation (PAD) – the use of an AED by members of the public before the arrival of the ambulance service – facilitates rapid defibrillation and improves survival to hospital discharge and survival with a favourable neurological outcome (69). The only large-scale randomised controlled trial (RCT) of PAD was conducted across 24 sites in North America (The PAD Trial). Researchers randomised trained responders to provide a cardiopulmonary resuscitation (CPR) and AED response (intervention group), or a CPR-only response (control group). Survival to hospital discharge in the intervention group was doubled (28/130 intervention vs 15/107 control; relative risk 2.0, 95% confidence interval (CI) 1.07-3.77) (114).

Registry data from the International Liaison Committee on Resuscitation (ILCOR) member countries report PAD use between 2.0-37.4% (either 2014 or 2015 data) (21). PAD occurred in only 4.5% of England's OHCA's in 2018 (12).

Low PAD rates result in an efficacious intervention having only a limited impact on OHCA outcomes at a population level. Understanding barriers to PAD use is vital to increasing its effectiveness and improving survival from OHCA.

## **4.2 AIM**

The aim in this chapter was to identify barriers and facilitators to the deployment and use of PAD by bystanders for OHCA patients.

## **4.3 METHODS**

### **4.3.1 Published systematic review (2017)**

I structured a published systematic review with reference to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) checklist (205) and registered it on the PROSPERO international prospective register of systematic reviews ([http://www.crd.york.ac.uk/PROSPERO/display\\_record.asp?ID=CRD42016035543](http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42016035543)).

This review considered all full-text English language articles published in peer-review journals, with no limit on publication date. It did not include abstracts or reports of conference presentations.

Two authors (**CMS** and **SLCK** – the latter not otherwise involved in this PhD) conducted an initial review of the literature. This had been done (in 2016) for a project not related to this PhD. They agreed key search terms and independently performed searches across PubMed and Google Scholar to identify full-text papers related to barriers and facilitators to PAD in OHCA and to confirm the need for a formal structured review of the literature.

I later updated this review (in February 2017) and subsequently developed a systematic electronic search strategy for MEDLINE (Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations March 06 and Ovid MEDLINE(R)

1946 to March Week 1 2017) and EMBASE (1974–2017 March 09) (Wolter Kluwers Health, <https://ovidsp.ovid.com/>). I ran the searches on 10<sup>th</sup> March 2017, and then performed a title and abstract search from which I identified full-texts for review. The electronic search strategies are available as an **appendix (Chapter 14)**.

I reviewed full-texts identified from both the initial review process and the electronic database searches. Following the electronic database search, I identified more relevant articles by: (1) Performing bibliography searches of included full-texts and (2) Using the 'Related Articles' feature of PubMed (<https://www.ncbi.nlm.nih.gov/pubmed/>) and Google Scholar (<https://scholar.google.co.uk>).

Although the work was published as a systematic review (111) it is, on reflection, more accurate to refer to it as a scoping review. This is for a number of reasons. The aim of the review was to identify the breadth of knowledge on this topic, and any potential gaps. The nature of the “barriers” was kept deliberately broad and, as such, I included any articles that concerned reasons affecting the likelihood of bystanders using PAD in an OHCA, and presented original and quantifiable data. Such broad inclusion criteria rather than a clearly defined research question, and the ability to examine what outcomes are reported rather than focussing on one particular outcome of interest mean that the work in this chapter would now more appropriately be considered a scoping rather than systematic review (208). This does not undermine the systematic and structured approach to data collection and synthesis that I undertook.

I excluded articles if they: were review or expert opinion articles with no primary data; related only to the acquisition of AED skills, without some qualification of how this might affect PAD in OHCA; related to AEDs that did not have the potential for public use; or related to AED use by ‘professional’ first-responder groups, such as the police, fire service or healthcare professionals such as Emergency Medical Services (EMS – ‘ambulance services’ in the UK).

I extracted the following data into a data collection form: study date and location; study design and key characteristics; and key findings about barriers and facilitators to PAD. I classified articles into different themes.

The topic of the review meant that there was great heterogeneity in the articles included. Many of the articles were observational in nature, with many collecting data retrospectively, or surveys. Such articles would represent low or very low-certainty evidence according to the Grading of Recommendations Assessment, Development and Evaluation (GRADE) criteria (209). I considered that the risks of selection-, information- and detection bias in observational studies, and response bias for surveys were high. It was not appropriate to assess accurate estimates of the effect size for a barrier or facilitator. Again, this overall assessment of the quality of the heterogeneous research studies presented, rather than a study-by-study risk of bias assessment, mean that the work in this chapter is better described as a scoping review rather than a systematic review (208). The heterogeneity of studies precluded meta-analysis.

#### **4.3.2 Update (2020)**

The systematic review was published in 2017. At the start of this PhD I set-up an automated search in PubMed to identify articles that might be relevant to any aspect of this PhD. I reviewed those pertinent to this chapter and also repeated the initial (2016) review process described above. I have provided an overview of relevant articles that I identified since 2017 in **section 4.5**.

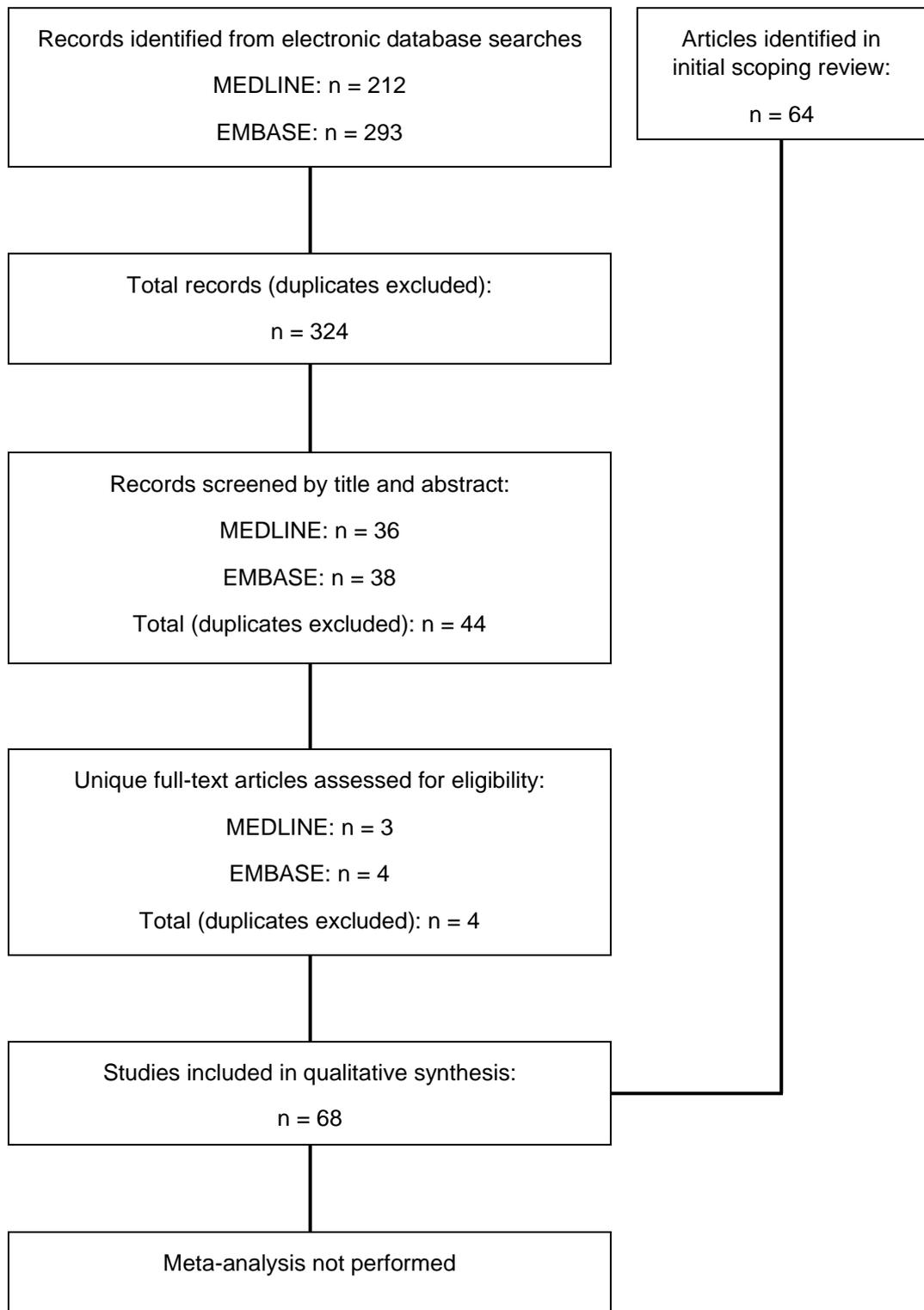
#### **4.4 RESULTS: PUBLISHED SYSTEMATIC REVIEW (2017)**

The selection of articles for inclusion in the published review is outlined in **Figure 4.1**. I identified 64 articles during the initial review (2016) (136,164,168,176-181,197,210-263).

The electronic databases searches returned 212 articles from MEDLINE and 293 articles from EMBASE. After removing duplicates there were 324 unique

articles. I selected 36 articles for full-text review from the MEDLINE search, and 38 from the EMBASE search – 44 articles in total after removing duplicates. I identified three additional unique articles (not already identified in the initial 2016 review) in MEDLINE ([264-266](#)) and one more in EMBASE ([267](#)), and included all four in the review. I identified no additional unique articles from bibliography and related-article searches.

I grouped the 68 included articles into eleven core themes covering user and system characteristics (**Figure 4.2**). The original data extraction tables are in the **appendix (chapter 14)**. Most of the articles were surveys or interviews, observational or other descriptive studies, or registry reviews.



**Figure 4.1: Study selection process – as it appears in published article (111), p266 – based on PRISMA flow diagram (205)**

<p><b>KNOWLEDGE AND AWARENESS</b></p> <ul style="list-style-type: none"> <li>- Limited knowledge of how/when to use AED (B)</li> <li>- Few know location of nearby AED (B)</li> <li>- Limited recognition of AED location signs (B)</li> <li>- Belief that AED are for use by trained personnel (B)</li> <li>- Varying knowledge of what an AED is (B,F)</li> </ul>	<p><b>WILLINGNESS TO USE</b></p> <ul style="list-style-type: none"> <li>- Fear of using AED incorrectly (B)</li> <li>- Fear of doing harm (B)</li> <li>- Lack of confidence in using AED (B)</li> <li>- Few people prepared to locate / retrieve AED (B)</li> <li>- Variation in number willing to use AED (B,F)</li> <li>- Belief that people should learn CPR/AED (F)</li> <li>- Few people had legal/liability concerns (F)</li> </ul>
<p><b>ACQUISITION AND MAINTENANCE</b></p> <ul style="list-style-type: none"> <li>- Cost, AED not being thought necessary, lack of responsible individuals, liability concerns were reasons for not obtaining AED (B)</li> <li>- Maintenance plans for AED often inadequate (B)</li> <li>- AED often obtained by donation/fundraising (F)</li> <li>- Previous OHCA / strong lobbyist key reasons for obtaining AED (F)</li> </ul>	<p><b>AVAILABILITY AND ACCESSIBILITY</b></p> <ul style="list-style-type: none"> <li>- Minority of OHCA occur close to an AED (B)</li> <li>- Many AED not accessible 24/7 (B)</li> <li>- Many AED in poorly accessible/visible areas (B)</li> <li>- AED often only available to on-site trained personnel (B)</li> <li>- Public-access AED used in few occasions when one was nearby and available (B)</li> <li>- AED-related adverse events are rare (F)</li> </ul>
<p><b>TRAINING ISSUES</b></p> <ul style="list-style-type: none"> <li>- Training increases knowledge and comfort about AED use (F)</li> <li>- Training increases willingness to locate and use AED (F)</li> </ul>	<p><b>REGISTRATION AND REGULATION</b></p> <ul style="list-style-type: none"> <li>- AED often not known to EMS or those running PAD schemes (B)</li> <li>- Regulation of AED may not affect survival chances if AED used (N)</li> </ul>
<p><b>MEDICOLEGAL ISSUES</b></p> <p>Single study (US):</p> <ul style="list-style-type: none"> <li>- No state mandates all AHA recommendations about PAD programmes in law (B)</li> <li>- Quality improvement rarely mentioned (B)</li> <li>- Civil immunity for rescuers a concern (F)</li> </ul>	<p><b>DISPATCH-ASSISTED AED USE</b></p> <ul style="list-style-type: none"> <li>- EMS refer minority of callers to nearby AED (B)</li> <li>- Volunteer responders alerted via text message by EMS connect AED first in some cases (F)</li> <li>- Simulation: dispatcher involvement allows quicker AED retrieval and correct use (F)</li> </ul>
<p><b>AED LOCATOR SYSTEMS</b></p> <p>Single Study (Japan):</p> <ul style="list-style-type: none"> <li>- Web-based AED location software did not reduce time to AED retrieval (N)</li> </ul>	<p><b>DEMOGRAPHIC FACTORS</b></p> <ul style="list-style-type: none"> <li>- Disagreements about the effect of age, gender, employment status, ethnicity and income on the ability or willingness to use AED (N)</li> </ul>
<p><b>HUMAN FACTORS</b></p> <ul style="list-style-type: none"> <li>- Few who believe in AED training have training themselves (B)</li> <li>- Rescuer-related adverse events, including stress, are low after AED use (F)</li> <li>- People trust the AED to perform as designed (F)</li> </ul>	<p>(B) Barrier (F) Facilitator (N) Neutral</p>

**Figure 4.2: Barriers and facilitators to Public Access Defibrillation. Key Themes – as it appears in published article (111), p267**

#### **4.4.1 Knowledge and awareness**

Fourteen surveys (210,213,215,223,232,233,238,254-258,265,266) and two qualitative interviews (263,267) reported on knowledge and awareness of PAD.

Overall awareness of the purpose of an AED ranged between 15-89% (213,215,223,232,238,254-258,265,267). One longitudinal survey from South Korea reported that awareness increased over time, from 6% in 2007 to 31% in 2011 (266). Knowledge about how to use an AED was less frequently reported (7-26%) (213,215,232,233,267). In two studies where survey respondents were questioned about a hypothetical scenario, only 6% (254) and 8% (265) spontaneously mentioned AED use as an appropriate treatment option.

There was limited knowledge about public-access AEDs and how to find them (263,265). Few people (5-22%) were able to locate their nearest public-access AED (213,215,223,232). Only 29% (238) and 40% (210) of respondents recognised standard AED location signs, designed to facilitate identification of a public-access AED,

There was a belief by some people (19-40%) that members of the lay public could use AEDs, not only by trained individuals or healthcare professionals (233,254,265).

#### **4.4.2 Willingness to use**

Thirteen surveys (213,215,223,231,232,237,238,254-258,265), three qualitative studies (228,263,267), one before-and-after study (244) and one RCT (239) reported on issues that relate to willingness to use public-access AEDs for OHCA.

Willingness of laypeople to use public-access AEDs varied markedly between 12-87% (213,223,231,232,237,238,244,254,256-258,265). 3% (215) and 30%

(223) indicated willingness to retrieve a nearby AED. When asked specifically about retrieving *and then* using an AED in a study in England, only 2% indicated willingness (215). Reasons for not being willing included: not knowing how the device worked (40-85%) (232,237,238,244,257,258) or not being comfortable using it (72% (213) and 84% (255)), fear of causing harm to the patient (14-88%) (213,231,232,244,254), and legal liability (4-38%) (213,231,237,254,257,258).

One qualitative study reported that “most” respondents would feel more comfortable waiting for someone who was more competent in AED use to avoid causing more harm to the patient (267). Qualitative interviews with laypeople trained in AED use revealed that they would be uncomfortable taking an AED to use in a distant location. Respondents cited a lack of clarity about their responsibility and potential liability in such a situation (228).

People were willing to obtain CPR and AED skills (88% (255)), and believed that this was relevant given increasing numbers of public-access AEDs (263).

A Danish survey of laypeople before and after a mass education and media campaign about CPR demonstrated a statistically significant increase in the number of people indicating that they were “definitely” willing to use an AED on a stranger from 44% to 65% (244). In Japan, more students and teachers indicated that they would “definitely” use an AED if required in 2014 (258) than in 2008 (257) (students 73% vs 12%; teachers 87% vs 35%). Willingness to use an AED increased in one US study from 71% to 83% if survey respondents were informed about legal liability protections for rescuers (237).

McDonald et al (239) conducted an RCT where a control group received a leaflet encouraging CPR and AED use, and the intervention group received the same leaflet with two additional “motivational” messages about CPR and AEDs. Both groups were laypeople with no previous experience of CPR. More people in the intervention group indicated that they would routinely check for a public-access AED (53% vs 37%,  $p < 0.03$ ) but there was no difference in the numbers reporting willingness to use an AED (40% vs 36%;  $p = ns$ ).

#### **4.4.3 Acquisition and maintenance**

Two observational studies (243,261), five surveys (211,212,217,218,230), and two qualitative studies (250,260) reported on acquisition and maintenance of public-access AEDs.

Public-access AEDs were often acquired by donation or fundraising (68% (243) and 58% (218) rather than private purchase, and donation was a predictor of AED acquisition amongst college athletic departments in one study (217).

Several reasons for not obtaining an AED were reported: Cost (32-38%) (212,217,218); concerns about liability (7-51%) (212,217,250); not being thought necessary (13%) or not being considered (24%) (212); lack of and/or attrition of responsible individuals (250); there was a good EMS response locally (33%) (217); and there was a nearby hospital (11%) (212).

One study reported that whilst 32% cited cost and 37% cited legal concerns as reasons not to obtain an AED, 55% thought affordability and 51% thought legal protection were good reasons to obtain an AED (217). Strong lobbying from trade unions, previous OHCA and a belief that having one would mitigate risk were also influential reasons to obtain an AED (260).

Maintenance of AEDs was variable. One study reported that all but one of 206 AEDs were “operable” and ready for use (261), but many AEDs were not maintained (24% (218)) or had no formal plans in place for maintenance (18%) or replacement (24%) (211).

#### **4.4.4 Availability and accessibility**

Twenty observational studies (176-181,214,216,222,225,227,234-236,241,246-248,251,261) and three surveys (197,211,218) reported on the availability and accessibility of public-access AEDs.

Only a proportion of OHCA will occur in areas suitable for PAD – estimates between 17-26% in three studies (222,247,251). There is often a poor correlation between risk of OHCA by location and placement of AEDs (214,225,235,236,241). In urban areas 3-25% of OHCA occurred within 100m of a public-access AED (176-180,227). In Philadelphia researchers estimated that 70-80% of OHCA would occur within 3 minutes' walk of an AED (216).

Public-access AEDs were deemed to be in poorly accessible areas in between 18-59% of cases (197,211,218,234,261) or not available all of the time. Out-of-hours there is a substantial reduction in AED availability (179,181), reported as 34% in one study (181). There was variation in the proportion of AEDs within 100m of an OHCA that were actually available for use at the time of the cardiac arrest (15-78%) (176,179,180). In the PAD Trial, AED-related adverse events affecting AED availability were reported in 1.5% of cases (246).

Actual usage rates of public-access AEDs within 100m of an OHCA by bystanders were reported as 30% (176) and 0.6% (177). In one residential trial site in the PAD Trial there was a PAD response (in the CPR/AED arm of the study) for only 25% of OHCA patients (248).

An analysis of temporal trends in Copenhagen (2007–2011) demonstrated an increase in AED numbers, including in high-risk areas and an increase in OHCA coverage. Despite this, only 3% OHCA in the time period occurred within 100m of an AED and only 9 had an AED applied before the arrival of EMS (227).

#### **4.4.5 Training issues**

Ten surveys (213,215,223,231,232,237,240,245,256,264), one observational study (226) and one qualitative study (228) reported on training issues affecting public-access AED use.

It was generally reported that previous training in CPR and AED use resulted in more people knowing what an AED is (77% vs 46% (223)); when to use an AED (79% vs 23% (232)); the location of the nearest public-access AED (39% vs 14% (223); 5% vs 0.3% (215); 84% vs 5% (232)); comfort levels in using an AED (50% vs 14% without assistance and 85% vs 48% with EMS assistance (213)); and who stated they would use an AED if required (42% vs 6% (223); 3% vs 0.3% (215); 25% vs 25% (232)). Knowledge of how to use an AED increased willingness to use in both those under 60 years of age (91% vs 42%) and over 60 years of age (87% vs 24%). Further, an increasing number of previous CPR training sessions resulted in greater willingness to use an AED (264).

However, a study from Singapore found that CPR training was more widespread than AED training (11% had been trained in AED use vs 31% trained in CPR) (245). Only one study – in high-school students – reported that prior AED training had no effect on willingness to use an AED (numbers not provided) (231).

In a written survey, greater training and knowledge were the most common reasons given that would increase willingness to use an AED (256). Offering training increased willingness to use an AED from 71% to 91% in another study (237). Successful use of an AED in training and greater perceived self-efficacy in AED use were both positively associated with willingness to use an AED (240). In qualitative interviews, in-situ scenarios rather than classroom-based training was felt to be more useful (228).

In the PAD Trial, volunteers who had actually responded to at least one medical emergency were more likely to have undertaken pre-trial CPR training and follow-up AED skills testing (226).

#### **4.4.6 Registration and regulation**

Two observational studies (136,249) and one mixed-methods study (242) reported on registration and regulation of public-access AED.

In Stockholm (2006-2012), 72% cases of public-access AED use were with AEDs not previously known to the city's PAD programme (136). In Washington state (2007–2009) 59% cases of public-access AED use were with AEDs not known to EMS (249). In a mixed-methods study to identify as many PAD locations as possible in North Carolina (2001–2002), 18% were already known to EMS (242).

Prior registration of an AED in Stockholm's PAD programme did not have any effect on survival to one month in patients who received shocks from public-access AEDs (71% 'regulated' vs 70% 'unregulated') (136).

#### **4.4.7 Medicolegal issues**

Only one article specifically examined the law around PAD and presented data on how this was being implemented (224). The American Heart Association (AHA) has guidelines outlining 13 recommended elements for the successful running of a PAD programme. There was no jurisdiction in the USA that mandated all 13 of these elements. Whilst there is often civil immunity for rescuers who use AEDs, legal protections for those who set-up and medically oversee PAD programmes is more scarce.

#### **4.4.8 Dispatch-assisted AED use**

Seven observational studies (164,168,176,180,220,243,249), three simulation RCT (221,229,252) and one other simulation study (238) reported on EMS Dispatch-assisted AED use.

AEDs, when available, were applied by members of the public after specific retrieval instructions from EMS in 4-41% cases (176,180,220,243), variably defined as present within 100m and available for use (176,180), an AED mentioned during emergency call (220), and the "nearest" AED (243). EMS-assisted AED use, where reported, occurred in 0.07-5% of the total number of OHCA in these studies (176,180,220). Another study reported that from 58

OHCA when an AED was available within 0.1 mile, EMS notified the caller about the AED in only 3 cases, and there were no AED applications (249).

Simulated OHCA scenarios have demonstrated that EMS dispatch assistance resulted in a shorter time to AED retrieval and defibrillation (252), and correct use of an AED in 62% (238) and 79% (229) of cases. In a simulation RCT of adults over 75 years of age, those receiving EMS assistance over the telephone were more likely than those who received no assistance to correctly deliver an AED shock (91% vs 68%;  $p=0.001$ ), although it took longer to do so (193s vs 148s,  $p = 0.001$ ) (221).

Volunteer first-responder systems, in which nearby lay responders are notified by EMS via text-message of a nearby OHCA, have resulted in responders being first to apply AED in 9% (164) and 12% (168) of the total OHCA in that system.

#### **4.4.9 AED locator systems**

One simulation-based RCT (253) reported that a web-based AED-locator software, accessible by mobile phone, made no impact on the time taken by bystanders to locate a nearby public-access AED and to bring it to an OHCA patient (mean 400s intervention groups vs 407s control,  $p = 0.92$ ), despite a reduction in total travel distance (606m intervention vs 809m control,  $p = 0.019$ ). The travel distances are worth noting as the actual distance to the AED in two simulated scenarios was only 120m and 170m.

#### **4.4.10 Demographic factors**

Seven surveys (213,237,240,245,254,264,265) and two observational studies (225,226) reported on demographic factors affecting public-access AED use.

Results from studies were variable. AED coverage was greater in areas where median household income and the proportion earning over \$40,000 was higher although, contrastingly, there was also a slight increase in percentage

unemployment (7% in 'high- access' AED areas vs 4% in 'low-access' areas). There were no differences between different races (225). AED knowledge was higher in North Americans compared to Europeans and 'Other' in one study (254). Another reported that no demographic factor affected knowledge about an AED or the ability to identify one (213), and age and gender had no effect on either in a third study (265). In Singapore, those who were male, under 35, spoke the Malay language, had A-levels or Diploma or who were currently employed were more likely to have been trained in the use of an AED (245).

One study (254) reported that women and those under 25 and over 60 would be less willing to use an AED, but another reported that more people aged 17-29 or male was associated with willingness to use an AED (264). Two further studies reported no age or gender differences in future willingness to use an AED (237,240). In the PAD Trial, age and gender had no effect on likelihood of having responded to an emergency, but ethnic minority status and formal education beyond high-school made it less likely that a person had responded (226).

#### **4.4.11 Human factors**

Three qualitative studies (219,259,262), one survey (245) and one observational study (246) reported on human factors affecting AED use.

Rescuer-related adverse events in the PAD Trial were rare, with only seven reported out of 20,396 volunteers trained (246). Four of these were due to emotional stress requiring intervention. In interviews first volunteer first-responders activated by text message in Netherlands, 81% reported no stress after the event, and the other 19% reported mild stress only. Not being able to attach an AED was associated with the likelihood of experiencing mild stress (262). People innately trust AEDs (259), and can develop an inbuilt resilience when responding with an AED (219).

People's beliefs about AED training differed from their actions in a study from Singapore. Although 57% believed all adults should train in AED use only 4% had been trained themselves and held up-to-date qualifications (245).

#### **4.5 RESULTS: UPDATE (2020)**

The update identified 25 further studies of interest.

##### **4.5.1 Knowledge and awareness**

In semi-structured interviews, bystanders at real OHCA (Denmark 2012–2015) reported that knowing that intervening can improve survival and knowing that the AED gives voice prompts and guides you through the resuscitative effort facilitated CPR and AED use (268).

Further studies suggest limited knowledge about AED function (269-271) and their location (269,271).

Surveys of schools (272,273) and sports facilities (274,275) with an on-site AED reported barriers to its use by staff, including not knowing its location and not having had appropriate training in its use (273,274) and a perceived lack of clarity or policy about its use (272).

##### **4.5.2 Willingness to use**

Two studies reported a limited willingness to use public-access AEDs for OHCA (269,271), including a UK-wide YouGov survey of 2000 adults in May 2017 (269).

##### **4.5.3 Acquisition and maintenance**

A lack of clear policy about who had responsibility for maintaining and deploying an AED was reported as a barrier to obtaining one in public schools (272). Organisations may need prompting to obtain an AED in the first

instance: in one interview of fourteen community sports organisations in Victoria, Australia, none had initially been aware of a state-wide programme to provide AEDs, and all of them only purchased an AED when directly informed of the opportunity to do so (275).

#### **4.5.4 Availability and accessibility**

A number of studies reported that public-access AEDs are often not sited 'close to' (variably described as within 100m or 200m) the location of historical OHCA (276-280). There are fewer AEDs available within a suitable distance for OHCA in residential compared to non-residential areas (280,281). The probability of bystander defibrillation was inversely associated with OHCA distance from the nearest public-access AED in three studies. In Denmark (2006–2013, 6971 OHCA), 36% patients received bystander defibrillation for their public-place OHCA if the nearest public-access AED was immediately adjacent or on-site; corresponding figures were 21% at 100m away and 14% at 200m. For residential OHCA, these figures were 7.0%, 1.5% and 0.9% respectively (280). In Montreal, Canada (2014–2015, 2443 OHCA), proximity to an AED was associated with a higher chance of bystander defibrillation once the nearest AED was within 400m of the OHCA, although estimates were imprecise due to bystander defibrillation being performed in a very small proportion of cases (3%, n=77) (282). For 337 bystander-witnessed OHCA in Copenhagen (2008–2016), the adjusted odds ratio (AOR) for bystander defibrillation was 3.3 (95% CI 1.6-7.0) if an AED was within a 200m walking distance, albeit in a model that adjusted for age and sex only (278).

Not all of these AEDs will be available for use. Calculating walking distance from a historical OHCA to its nearest AED, rather than straight-line distance (radius), reduces the estimate of available AEDs (276-278). More studies confirm that AEDs are often not accessible at the time of the OHCA (276,278,279). A study of 566 OHCA in Copenhagen occurring within a 200m walking distance of an AED (2008–2016) reported that 49% of the AEDs were inaccessible at the time of day that the OHCA occurred (278).

Only five of 201 public-access AEDs inspected in Southampton (2017–2018) had visible signage remote from the AED guiding viewers to its location (283).

#### **4.5.5 Training issues**

Bystanders at real OHCA (Denmark, 2012–2015) believed previous hands-on CPR/AED training facilitated CPR and AED use during the OHCA (268).

Training improved – self-reported, at least – knowledge and willingness to use in two studies (269,271). The UK-wide YouGov survey in May 2017 reported that those trained in the use of an AED were 2.6 times more likely to use a public-access AED in an OHCA (269).

#### **4.5.6 Registration and regulation**

Registry-based information about accessible AEDs can soon become out of date: researchers in Sweden increased the number of registered AEDs in a national database from 7287 to 15,849 (2013–2016). However, this final number was after 6703 (30%) were removed because researchers could either not validate that they were functional or that they existed at all (284).

#### **4.5.7 Dispatch-assisted AED use**

An AED was reported available (by automatic prompt in the EMS dispatch system or by the bystander themselves) in 5.8% (1091/18904) emergency calls for confirmed or potential OHCA in 14 US states (2014–2018). Call-handlers asked a bystander to retrieve a public-access AED on 53% (579/1091) occasions but the bystander failed to retrieve it for 72% (417/579) of these calls (285).

#### **4.5.8 Demographic factors**

In a US survey of 9022 people (2015), those identifying as white (AOR in a multiple logistic regression model of 1.90, 95% CI 1.43-2.53) or black (AOR

1.73, 95% CI 1.39-2.15) were more likely than those identifying as Latino to have had AED training (286). In 22,816 OHCA across the USA (2008–2011) the likelihood of bystander AED use decreased with increasing proportion of black residents in a neighbourhood (reported by centile, <25%, 25-50%, 50-75%, >75%) (authors' terminology in both papers) (77).

In a study of 61,473 OHCA in the USA (2011–2015) female patients were less likely to have an AED attached during public-place OHCA (AOR 0.76, 95% CI 0.64-0.90). This was true even when only considering cases where any bystander intervention had occurred (AOR 0.83, 95% CI 0.71-0.99) (287), suggesting an effect that was specific to AED use and not to bystander intervention in general during OHCA.

#### **4.5.9 Human factors**

Bystanders from real OHCA (Denmark, 2012–2015) reported that a perceived moral obligation to help facilitated their CPR and AED use during the event (268).

#### **4.5.10 Drone delivery of AEDs**

A number of studies identified since 2017 have focussed on the specific use of Unmanned Aerial Vehicles (UAVs) or 'drones' for OHCA, and so it warrants its own theme.

In Toronto, modelling suggests that optimising locations for a regional drone network could deliver AEDs to greater than 50,000 historical OHCA (2006–2014) more than six minutes (in urban areas) and more than ten minutes (rural areas) faster, compared to the 90<sup>th</sup> percentile for emergency service response time (288). Modelling from researchers in Stockholm County, Sweden, demonstrated that drones could be delivered to scene of 3165 historical OHCA (2006–2013) a mean of 1.5 minutes earlier than the ambulance service in urban areas and 19 minutes earlier in rural areas (289). In test flights from the same researchers, a drone reached the site of 18 historical OHCA (located a

mean of 3.2km away from the drone launch site) a mean of 16.4 minutes earlier than the EMS response to those cases (290). In a simulation study, eight bystanders found interacting with a drone-delivered AED easier than other aspects of the resuscitation effort (291).

## **4.6 DISCUSSION**

### **4.6.1 Main findings**

The published systematic review and subsequent update highlights a number of key barriers to Public Access Defibrillation. Few people know what an AED is, where to find one, or how and by whom one can be used. Studies report a variation in the proportion of people willing to use an AED, but a lack of confidence and fear of harm are common themes affecting willingness. Many organisations do not feel that they should obtain an AED or feel unable to do so. Only a minority of OHCA occur in locations suitable for the timely deployment of a public-access AED. AEDs are often poorly accessible or have limited availability, and are often not known to EMS or those running PAD schemes.

Training increases awareness of AED function, comfort with and willingness to use one, but more people believe in the value of AED training than have actually received it. There are no consistent findings to suggest that any one section of society is more or less willing or able to use an AED.

Novel means of dispatching an AED to the scene of an OHCA may facilitate rapid bystander AED use and needs further exploration. I have not considered studies examining AED delivery by dispatched volunteer first-responders in this chapter here as this is the focus of later parts of this PhD.

### **4.6.2 Comparison with the literature**

Capital investment and efforts to increase public-access AED numbers are commendable, but it is at least as important to maximise use of the resources

that are currently available. I did not include papers reporting only about public-access AED density in the review, unless they reported how this facilitates or impedes their use. The link between the number or density of public-access AEDs and clinical outcomes is not yet clear. In a 5-year evaluation (2005–2010) of PAD in 51 French districts, AED density was not an independent predictor of survival to hospital discharge in a multiple logistic regression model (AOR 1.08, 95% CI 0.78–1.49) (292).

Researchers can model the optimum location or location types for public-access AEDs to provide effective coverage for as many OHCA as possible, using historical OHCA locations to guide them (151,178,293-295). A common problem, though, seems to be that AED located close to an OHCA are not always available for public use (176,180,181), particularly ‘out-of-hours’ when many OHCA occur (181,276,278,279). Targeted location of AEDs will be most effective if combined with efforts to improve actual availability.

A focus on the fact that PAD is available and safe for all bystanders to use (6,67), regardless of previous training, would also be useful. However, findings from this review indicate that prior training and experience affect willingness to use PAD in OHCA, and many other studies have reported that bystanders who do intervene often have some form of medical or first-aid training (139,243,296). There must be a balance between emphasising that public-access AEDs can be used by untrained bystanders, and emphasising that widespread training is likely to contribute to increased PAD.

Increased survival has been demonstrated in patients who receive PAD before the arrival of EMS from ‘public-place’ AEDs compared to AEDs brought to scene by community first-responders (118,128,136). The effective coverage range of an AED (i.e. the distance from an AED that an OHCA can occur for its retrieval to be of potential benefit) has not been determined, although 100m (176-178,180) and 500m (168) have been suggested in published studies. Studies published since the 2017 systematic review recognise the need to determine ‘real-world’ walking distance rather than straight-line distance to the

nearest AED (276-278). Determining the likely effective range of a public-access AED will help optimise their placement in the future.

There is substantial potential for ambulance service dispatchers to provide telephone assistance to help bystanders locate and use AEDs, but this rarely happens at present. In addition, mobile-phone-activated app-based systems can direct lay responders to OHCA to provide CPR and PAD (164,168): these and similar mobile phone app-based systems are the focus of much of the remainder of this thesis. The future should include both these approaches, as well as other means of rapid one-way AED dispatch to OHCA patients.

Comprehensive AED registries, linked to OHCA registries, will be important in locating public-access AEDs. They should help researchers modelling where to locate public-access AEDs, and ambulance dispatchers guiding bystander resuscitation efforts during an emergency call. However, it is important they are up to date (284).

#### **4.6.3 Strengths and limitations**

This was a wide-ranging review, collating a large amount of information about reasons for the low use of public-access AEDs seen in populations across the world. It provides an idea of the main barriers to successful AED deployment, and this will allow researchers to better consider the design of interventions to overcome these barriers.

The wide-ranging nature of the topic “barriers and facilitators to PAD” made choosing search terms for electronic database searches problematic. It was difficult to be inclusive whilst retaining a feasible number of articles to review. The approach used in this paper of an extensive literature review using existing expert knowledge, later re-enforced by a systematic search across electronic databases, was a good compromise.

Doubtless, these problems, and the overlap with articles reporting on bystander CPR (with which PAD will be intrinsically linked) mean that there

doubtless are articles that I have failed to include. In a similar manner, there may have been papers primarily reporting clinical outcomes that may also include secondary information about barriers or facilitators to PAD, which I will have failed to identify in title and abstract searching.

This review did not consider conference abstracts or information in the grey literature. I have attempted to systematise what was essentially a narrative review, and so this paper represents the most comprehensive review of barriers and facilitators to PAD deployment in OHCA to date. The vast majority of the reviewing was done by me alone – this being work contributing to my PhD submission – and so there was no opportunity for me to discuss or resolve omissions or errors in article identification process with a second reviewer.

There was great heterogeneity in how the surveys reported in this review were performed (e.g. face-to-face, written, online; with open questions or semi-structured questionnaires). None of the questionnaires were subject to any external validation, and all surveys are subject to response bias. Database and registry reviews are reliant upon the accuracy and completeness of the data recorded in them. The RCTs reported were small-scale, and all but one involved simulation-based OHCA scenarios.

Although the majority of the evidence would be considered low- or very-low certainty according to GRADE criteria ([209](#)) there was no formal risk-of-bias assessment for each individual article. This was a reasonable approach. Ultimately, this was a wide-ranging scoping review identifying key themes about barriers and facilitators to PAD. It was not a systematic review answering a clearly defined research question about a specific barrier or facilitator and its effect on a specific clinical outcome ([208](#)). Nonetheless, I chose which themes to report myself – they were not based on any existing framework. In such an approach it is possible to try and fit new data into one's existing theme(s) and to misclassify it. Formal thematic analysis is a skill gained over time, and one which I have attempted to demonstrate – with appropriate supervision – in later parts of this PhD (**chapter 8** in particular).

#### **4.6.4 Clinical implications**

PAD is a proven clinical intervention that is infrequently used, and so it is an excellent target for interventions to increase its use. Many of the articles were either surveys or observational in nature, and there was great heterogeneity in how studies were conducted. This chapter then, highlights weaknesses in much of the work done to highlight barriers and facilitators to PAD. The available evidence in both the published systematic review and from the articles reviewed since then should not be used to directly inform changes in policy in practice, and I do not advocate for this.

What is striking from the articles presented in the systematic review and its 2020 update is that more report on barriers rather than facilitators to PAD. There is also a lack of information about how to overcome these barriers, or find and test solutions in order to improve PAD. One notable study that did report on facilitators was conducted in Denmark. Researchers conducted 128 semi-structured interviews (2012–2015) with CPR-trained, non-healthcare provider bystanders who had attended an OHCA where there was an AED present. They selected 26 of these interviews for in-depth assessment using a thematic analysis to identify potential facilitators to CPR and AED use in “real” OHCA. They iteratively assessed transcripts to generate relevant codes and organised these into relevant themes using a pre-specified data analytical process (268). This study provided a robust and well-described method that was lacking from much of the other available research.

#### **4.6.5 Next steps**

It would be appropriate to develop a robust approach to develop theoretically-informed interventions to overcome barriers to PAD. Validated frameworks to categorise data related to individuals’ behaviour do exist, such as the Theoretical Domains Framework (196), which could be used to identify behavioural themes related to decisions about AED use. This framework can be linked to validated models that identify behavioural changes (198) and suggest how this change can be achieved (199).

## **4.7 CONCLUSION**

PAD can improve OHCA survival, but its effect at a population level is hampered by low usage rates. The low-quality evidence presented in this chapter should not be used alone to directly inform changes in policy or practice. An increase in PAD will require robust methods both to identify barriers and then to overcome them with theoretically-informed interventions.

# CHAPTER 5

## The GoodSAM first-responder app for out-of-hospital cardiac arrest

---

**Part of this chapter has already been published (174):**

**Smith CM**, Wilson MH, Ghorbangholi A et al. The use of trained volunteers in the response to out-of-hospital cardiac arrest – the GoodSAM experience. *Resuscitation* 2017;121:123-6

---

GoodSAM is a mobile-phone, app-based alerting system allowing the notification of trained volunteer first-responders to a nearby out-of-hospital cardiac arrest (OHCA). This response is designed to be in addition to rather than a replacement for the statutory ambulance service response.

Before this PhD there had been no scientific evaluation of GoodSAM to determine its effect on patient survival or on other metrics such as bystander cardiopulmonary resuscitation (CPR) or bystander Automated External Defibrillator (AED) use. This chapter is a description of the GoodSAM app, focusing on its use for potential OHCA. Other uses for the app are briefly described in **section 5.4.2**. The PhD focuses on the use of the GoodSAM responder app for OHCA by London Ambulance Service (LAS) and East Midlands Ambulance Service (EMAS).

## **5.1 DEVELOPMENT**

In 2012, London Air Ambulance doctors were concerned that trauma patients with isolated traumatic brain injuries were dying because of ‘Impact Brain Apnoea’ – which can occur after traumatic brain injury and is associated with airway obstruction (297) – who could be saved if bystanders delivered prompt but basic interventions. They soon recognised the importance of using trained volunteers to provide early intervention to the far larger population of OHCA patients.

Subsequently, GoodSAM developed a not-for-profit, mobile-phone app-based system alerting trained volunteers about nearby OHCA. A pilot scheme with LAS and London Air Ambulance staff demonstrated the accurate use of Global

Positioning System (GPS) navigation to locate responders' phones in real-time.

GoodSAM has an 'alerter' and a 'responder' app that can be used on any smartphone in any location in the world. Activation of the alerter app allows bystanders at the scene of an OHCA to request help from volunteer first-responders, whilst the app simultaneously dials the emergency number of that country. The Responder app allows registered responders to receive an alert (by 'push' notification on the mobile phone screen and an audible siren) about a nearby OHCA. GoodSAM responders can then 'accept' or 'reject' an alert.

The main use of the app for OHCA has come following integration of the responder app with local ambulance services. Automated systems alert nearby responders via the app when a call-handler recognises an OHCA during an emergency (999) call. In October 2015, LAS were the first to integrate GoodSAM with their dispatch systems. Their initial priority was to reduce time to first CPR, with no specific focus on bystander AED use. By the end of 2019, GoodSAM was integrated with the ambulance service in seven of the ten ambulance service regions in England, in Northern Ireland and Wales, in parts of Scotland, in Victoria state (Australia) and in New Zealand.

The GoodSAM app is available across multiple platforms (Android, iOS, Windows). It is an internet, cloud-based platform and does not require specific software to integrate with ambulance services. Start-up and maintenance costs are modest.

## **5.2 GOVERNANCE**

GoodSAM is funded by The Big Lottery Fund and The Cabinet Office – administered through the innovation charity Nesta (<https://www.nesta.org.uk>) – to develop and integrate the platform with ambulance dispatch systems in NHS trusts nationwide.

GoodSAM categorises its responders into three categories:

- Tier 1: Doctors, nurses, paramedics – governed at a national level
- Tier 2: Community first-responders, Emergency Medical Technicians – governed at a regional level
- Tier 3: Individuals with current training in CPR/AED, but under no formal governance

In the UK, all responders must have either valid professional healthcare registration – requiring an upload of a workplace ID and confirmation of registration with the relevant regulatory body – or a recognised, up-to-date CPR training certificate. Non-healthcare-professional ('lay') responders indicate whether their CPR course included training in AED use and are responsible for ensuring that their skills are up-to-date. There are mechanisms to renew or revoke registration if training certificates expire.

In Victoria and New Zealand, there is no requirement for lay responders to have formal CPR certification, but they are asked to ensure that their skills and knowledge are current.

Ambulance, fire, police and voluntary rescue services can register as organisations on the GoodSAM platform and approve their own staff as volunteer first-responders. Responders working for those organisations will be verified by them, and should be aware of any Standard Operating Procedures (SOPs) about responding via GoodSAM. GoodSAM performs verification of all other responders.

Everyone registered with the app should be familiar with GoodSAM's Code of Conduct (298). GoodSAM expect that most people will respond on foot but if they do drive to the scene they should do so in accordance with national driving rules. Responders should not attend an OHCA if they are impaired for any reason (e.g. after having consumed alcohol) or feel it is unsafe for them to do so. They should not act in excess of their ability to provide help. For the majority of people this means providing CPR and using an AED, although

healthcare professionals that routinely carry additional life-saving equipment may use it if appropriate. In all cases, the local ambulance service has overall responsibility for the patient and a GoodSAM responder, if they arrive at the patient first, should hand over control to the ambulance service as soon as it is safe to do so. They may continue to provide assistance if requested and they are competent to do so.

In the UK, there have been no instances of successful litigation against any individual who has intervened to provide life-saving treatment to an OHCA patient (127). The Social Action, Responsibility and Heroism Act 2015 (for England and Wales) (299) potentially provides protection to volunteers intervening ‘heroically’ but responsibly in an emergency. There is no case law. Issues regarding legal liability and registration vary in different countries, and GoodSAM users should clarify the situation where they live.

There is no obligation for a GoodSAM responder to accept an alert or attend an OHCA. However, again, this has not been tested by case law and GoodSAM might have to share data about an OHCA response if required by law. However, by not attending, a responder is not denying or affecting a statutory ambulance service response in any way.

The Medical Protection Society, a medical defence organisation in the UK, have said that they consider doctors using GoodSAM in the UK to be acting in a ‘Good Samaritan’ capacity, providing that they comply with the GoodSAM Code of Conduct. Doctors are advised to check with their specific medical defence organisation that they are covered for Good Samaritan acts (see <https://www.goodsamapp.org/faq>). Ambulance service staff in the UK who are verified by their employing Ambulance Service NHS Trust will usually be covered by trust indemnity provided they act within the limits of their skill and training. Following an alert, a responder has the option to record what happened on scene and what actions they performed. This post-event feedback remains available to the responder in case it is required in the future.

GoodSAM has a detailed Data Protection policy (300), complies with the General Data Protection Regulation (GDPR) and is registered with the Information Commissioner’s Office (no: ZA094052). Data is encrypted using a 256-bit Advanced Encryption Standard (AES-256) cipher. Although there is some limited and necessary sharing of data when a responder accepts an alert (e.g. local ambulance services will have access to information about responders’ locations and limited information about their skills), no data are shared with other third parties.

### 5.3 INTEGRATION WITH UK LOCAL AMBULANCE SERVICES

Integrating GoodSAM with local ambulance dispatch systems allows automated alerting of nearby volunteer first-responders when a call-handler diagnoses a potential OHCA during an emergency (999) call.

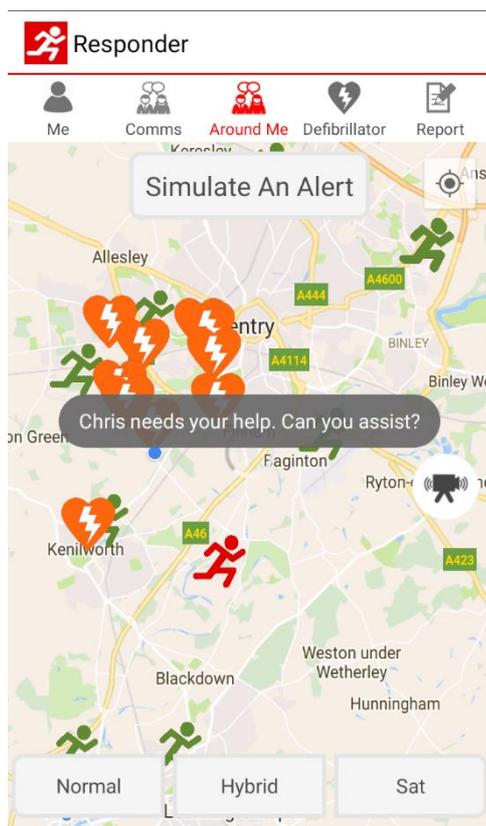
Both LAS and EMAS use a version of the Medical Priority Dispatch System (MPDS). During a 999 call, the GoodSAM system is automatically activated when a call-handler allocates an MPDS code – on a computerised dispatch system – indicating a possible OHCA. Each ambulance service can decide on the criteria required for a GoodSAM activation. **Table 5.1** shows the criteria used by LAS and EMAS.

**Table 5.1: Criteria for GoodSAM activation following potential OHCA**

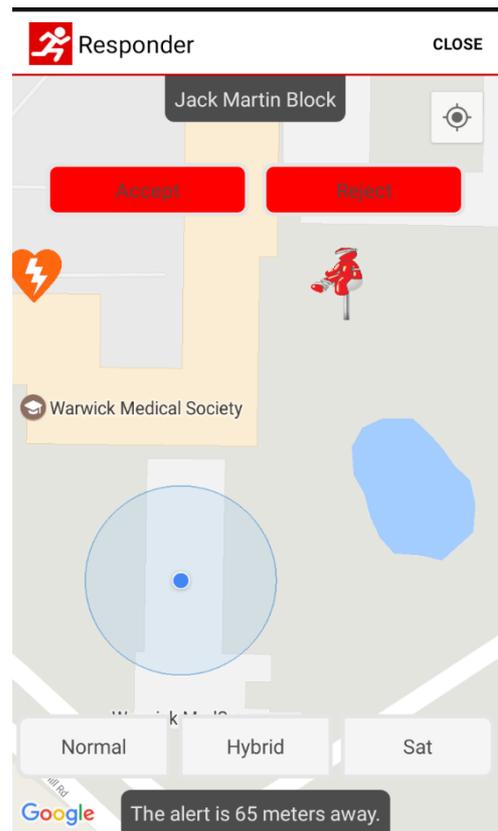
<b>London Ambulance Service</b>	<b>East Midlands Ambulance Service</b>
Cardiac arrest – not breathing at all	Breathing problems – ineffective breathing
Respiratory arrest – breathing uncertain (agonal)	Burns/explosion – unconscious or cardiac arrest
Respiratory arrest / ineffective breathing	Cardiac / respiratory arrest
Complete obstruction / ineffective breathing	Chest pain – not alert / breathing problems
Fitting and not breathing	Choking – complete obstruction
Fitting and not breathing – Fitting History	Convulsions – not breathing
Unconscious or fainting – Ineffective breathing	Drowning – unconscious or cardiac arrest

Unconscious, agonal / ineffective breathing	Electrocution – not breathing
	Fall – unconscious or cardiac arrest
	Heart problems – not alert / just resuscitated
	Unconscious or cardiac arrest
	Unconscious or cardiac arrest
	Unconscious fainting – ineffective breathing
	Unconscious fainting – agonal breathing
	Unknown problem – life status questionable
	Call from 111 – possible cardiac arrest
	Call from 111 – unconscious and ineffective breathing
	Call from 111 – 8 Minute response required

The app uses the smartphone’s GPS functions to track real-time responder locations, and if a responder is within a specified distance of the suspected OHCA, they will receive an alert to their phone. They can choose to ‘accept’ or ‘reject’ the alert at this point by a single button push. If the GoodSAM responder does not hear the alert siren or respond to it, the alert will remain active for up to 15 minutes. **Figure 5.1** shows the screens, sequentially displayed, in a simulated alert. Screen two automatically loads after screen one, and shows the location of the responder, the patient and a nearby AED (orange heart with lightning bolt symbol). The location of the responder and patient remain displayed on the screen, and the responder’s position updates as they travel to the patient. In a real alert, the screen displays a brief descriptor for the responder, based on the criteria in **Table 5.1** e.g. “cardiac arrest – not breathing at all.”



Screen one



Screen two

**Figure 5.1: GoodSAM alert (simulated). Screen one shows nearby responders (green and red figures) and AEDs (orange hearts with lightning bolt). Screen two shows responder location (blue dot), patient (injured figure) and a nearby AED.**

In MPDS, one only code can be 'active' at any one time. If a code is changed during the 999 call to one not indicating OHCA, there is an automatic stand-down of the GoodSAM alert. Similarly, if an initial 'non-OHCA' code is changed to one indicating potential OHCA later in the call, GoodSAM is activated at this point.

In London, GoodSAM alerts up to three responders within a 400m radius (for Tier 3 responders) or 700m (for Tier 1 or 2 responders). GoodSAM and LAS increased the alerting radius in London from 300m in 2018 partly in response to findings from **chapter 6** of this PhD. If one or more responders does not respond to the alert or indicates that they are not attending, the next nearest responder(s), if available, is alerted (up to three in total). GoodSAM launched

with EMAS in June 2017. Here, the ambulance service elected to send an alert to (up to) the nearest five GoodSAM responders within an 800m radius of an OHCA.

A real-time resource map is available for verifying organisations such as ambulance services. This allows the organisation to locate all its members and request assistance from either specific individuals or multiple appropriate resources in certain circumstances, such as when a major incident is declared. Ambulance services can also adjust dispatch rules so that only certain tiers of responders are alerted about certain events. For example, EMAS have a list of criteria for which there is an ‘enhanced’ GoodSAM response (rather than the ‘standard’ response criteria in **Table 5.1**). EMAS have set up GoodSAM so that only certain types of responder *verified by them* are alerted for an enhanced response. This includes potential OHCA caused by assault, road traffic collision, stabbing or shooting.

Ambulance services have the capability to adjust the response radius based on the tier of responder or by geographical area: for example, one could set a smaller response radius for a densely populated urban area with a short ambulance response time than in a more sparsely populated rural area.

Neither 999 call-handlers nor ambulance staff dispatched to an emergency call know whether or not there has been a GoodSAM alert – the system activates automatically and in the background. This avoids distraction and mitigates against any possibility of changing the existing ambulance dispatch based on knowledge of the GoodSAM response.

## **5.4 FUNCTIONALITY**

### **5.4.1 OHCA response**

Once download to your smartphone, the app runs in the background. Since April 2019, users can set-up the app so that the alert siren sounds even if the phone itself is in silent mode. Users need an internet connection to accurately

map their location in real-time, but people that live in areas with poor coverage can register their usual location on the GoodSAM website and sign-up for text-message alerts to alert them of OHCA's near to that area.

Users can open the app at any time – not just during an alert – to see a map showing the location of other responders and AEDs in their area. During an alert, it is possible to communicate with other responders by either text or audio message and responders can see the location of AEDs relative to both them and the OHCA scene. The responder does not have direct contact with the 999 call-handler at any time during the alert.

Ambulance services share information about AEDs known to them with GoodSAM. In addition, GoodSAM allows registered users to add the location of a public-access AED to the app themselves. They take a photo of the AED using their smartphone camera, with location data enabled, and upload it via the app. This AED will be displayed on the app once GoodSAM have verified its location. All AEDs verified by GoodSAM are displayed as orange hearts with a lightning bolt through it (see **Figure 5.1**). AEDs that have had additional functionality (e.g. battery life) checks by a local emergency service or voluntary aid organisation, are red. GoodSAM recommends that if one of its responders retrieves an AED during an alert they should preferably choose one marked red if there is an option.

During the upload process users can add text information, including availability hours, specifics about the AED location, and codes for AEDs kept in locked cabinets. This information is not always provided. For example, LAS decided *not* to record the availability of AEDs registered with them, and so do not share this with GoodSAM. They had received case reports where an AED was obtained outside of its supposed availability hours (e.g. in a locked office building out-of-hours, by alerting a security guard). The reasoning was that if there are enough bystanders at an OHCA and an AED *might* be available nearby, there may be a means of retrieving it.

GoodSAM responders can also indicate via the app if they have access to their own AED and keep it with them. The responder icon on the app is now displayed holding an AED.

By 2020, GoodSAM had more than 40,000 responders for OHCA worldwide and had located more than 50,000 AEDs.

#### **5.4.2 Other uses**

The GoodSAM responder app can transmit video from the scene to the ambulance service Emergency Operations Centre (EOC). Further, 999 call-handlers can send a text message to the person making the emergency call who, by clicking on the link contained within, can open up their phone's camera and relay video to the EOC. This does not require the GoodSAM app to have previously been downloaded onto the mobile phone. Streamed video is received by the ambulance service and can be encrypted and securely stored by them if desired, in the same way that audio 999 calls are currently stored (and subject to the same data protections). Video is not stored on the GoodSAM responder's phone at any time. Real-time video analysis of breathing and pulse is possible using an Artificial Intelligence algorithm.

Video streaming is also being used to aid decision-making in more complex incidents. In a feasibility study from 21 emergency calls to the London Helicopter Emergency Medical Service (HEMS), all those calling 999 agreed to click a text message link and share video. A live video stream was viewed in the EOC on 19 occasions, helping dispatchers decide to dispatch a helicopter in five cases and to stand-down the helicopter in 14 cases ([301](#)). There are further potential applications for on-scene video assessment by the police and fire service.

'GoodSAM Volunteer Response' has been used since March 2020 as the delivery platform for 750,000 volunteers as part of the NHS' response to the COVID-19 pandemic ([302](#)).

## **5.5 CONCLUSION**

GoodSAM is a mobile-phone, app-based technology. It was developed for OHCA and has been integrated into the dispatch systems of several ambulance systems to alert volunteer first-responders about nearby OHCA's. Its ultimate aim is to increase the number of people who survive following OHCA but, prior to this PhD, there was no work evaluating its effect on clinical outcomes.

## CHAPTER 6

The effect of the GoodSAM first-responder app on survival to hospital discharge following out-of-hospital cardiac arrest

## **6.1 INTRODUCTION**

Around one in ten people survive to hospital discharge after an out-of-hospital cardiac arrest (OHCA) in England (12). The most recent Ambulance Quality Indicator data from April 2019 – February 2020 showed that these figures were 8.6% (312/3646) in London and 7.8% in East Midlands (197/2540) (22).

Both London Ambulance Service (LAS) and East Midlands Ambulance Service (EMAS) have integrated the GoodSAM first-responder mobile-phone app (174) with their dispatch systems. During a 999 call, when an emergency call-handler suspects OHCA, the GoodSAM system will automatically send an alert via the app to trained responders within a specified radius of the OHCA incident, asking if they are able to respond.

Bystander cardiopulmonary resuscitation (CPR) and defibrillation using an Automated External Defibrillator (AED) can at least double survival from OHCA (6). It is therefore plausible that providing OHCA patients with early access to trained bystanders capable and willing to provide these interventions could impact upon survival.

## **6.2 AIM**

The aim in this chapter was to determine the effect of introducing the GoodSAM first-responder app in London and East Midlands on OHCA survival to hospital discharge.

## **6.3 METHODS**

### **6.3.1 System description**

LAS cover an area of approximately 620 square miles. It serves a population of 8.9 million people, with over 30 million more people visiting the area each year. It handled over 1.8 million 999 calls and attended 1.1 million incidents in 2016/17 (303). EMAS cover an area of approximately 6425 square miles,

serving approximately 4.8 million people. In 2015/16 it handled over 939,000 999 calls and attended over 659,000 incidents (304).

GoodSAM alerts responders who are within a specified radius of a suspected OHCA – this radius was 300m for LAS and 800m for EMAS during the respective study periods. If one or more of these responders rejects the alert, GoodSAM alerts the next nearest responder within the specified radius, until up to a maximum of three responders in London and five in East Midlands accept an alert. Alerts are accepted or rejected by button press in-app following an audible alert siren. GoodSAM integrated with the dispatch systems of LAS in October 2015, and with EMAS in June 2017.

In both LAS and EMAS 999 call-handlers use the Medical Dispatch Priority System (MPDS) to allocate a code that best categorises the problem being reported. Each ambulance service has determined codes that are used to indicate a potential OHCA (see **Chapter 5, Table 5.1**), and GoodSAM sends out an alert if one of these is allocated.

### **6.3.2 Data sources**

#### *Out-of-Hospital Cardiac Arrest Outcomes registry*

LAS and EMAS both submit data on OHCA's of any aetiology when the ambulance service either initiated or continued resuscitation.

I signed a formal data sharing arrangement with the Out-of-Hospital Cardiac Arrest Outcomes (OHCAO) registry at the University of Warwick on 23<sup>rd</sup> April 2018 for access to LAS data (1<sup>st</sup> April 2016 – March 31<sup>st</sup> 2017), and on 6<sup>th</sup> February 2019 for EMAS data (June 18<sup>th</sup> 2017 – June 17<sup>th</sup> 2018). I chose these dates as they were shortly after the roll-out of GoodSAM in each ambulance service region, but long enough afterwards so that the system had been fully established.

## *GoodSAM*

The University of Warwick (on my behalf) signed a data-sharing arrangement with GoodSAM on 17<sup>th</sup> December 2017 for access to information about alerts in London and East Midlands covering the same respective time periods as the OHCAO registry data.

### **6.3.3 Data collection**

I collected data on OHCA and GoodSAM alerts in London between 1<sup>st</sup> April 2016 – 31<sup>st</sup> March 2017 and in East Midlands between 1<sup>st</sup> January – 17<sup>th</sup> June 2018.

I collected the following data from the OHCAO registry (from both ambulance services unless indicated):

- Patient age (years)
- Patient gender
- Date of 999 call
- Time of 999 call
- Time ambulance vehicle stops
- Location of OHCA
- OHCA witnessed by (EMS\*/bystander/unwitnessed)
- Bystander CPR performed
- Public-access AED used by public (LAS only)
- Initial cardiac arrest rhythm (ventricular fibrillation or ventricular tachycardia (VF/VT), pulseless electrical activity (PEA), asystole)
- Return of Spontaneous Circulation (ROSC), at hospital handover
- Survival to hospital discharge

(\*EMS = *Emergency Medical Services* or 'ambulance service' in the UK)

I calculated the ambulance response time as the difference between 'Time ambulance vehicle stops' and 'Time of 999 call'. EMAS did not submit information on 'Public-access AED used by public' to the OHCAO registry.

The Health Research Authority's Confidentiality Advisory Group (CAG) reviewed these data fields at the behest of the OHCAO registry before the first data-sharing arrangement was agreed. They deemed all of these data non-patient-identifiable.

GoodSAM provided the following information in both ambulance service areas:

- Number of 999 calls meeting criteria for GoodSAM alert
- Number of GoodSAM alerts sent out
- Date and time of GoodSAM alert
- Number of GoodSAM alerts accepted, not seen or rejected
- Location of incident

I manually matched cases submitted to the OHCAO registry with GoodSAM alerts using date/time of the 999 call and OHCA location. GoodSAM recorded incident location as latitude and longitude. LAS provided address details and postcode. EMAS routinely provided location type as per Utstein definition (9) (e.g. residential, public building, street, workplace) but this was supplemented by postcode for 2018 data. The original protocol called for data collection for EMAS to start on June 18<sup>th</sup> 2017, but I could not accurately match 2017 GoodSAM alerts to the respective EMAS OHCA incidents as no postcode data was available. There were often multiple GoodSAM alerts across the region at around the time of a confirmed OHCA, and the Utstein definition alone was not enough to make a confident match.

For LAS data, I manually determined whether each OHCA had occurred in a residential or non-residential location by reviewing the address field in the OHCAO data submission. I dichotomised the location type provided in the EMAS dataset. If there was ambiguity I used Google Street View to review the

location and make a determination. I considered that OHCA at care homes, prisons and detention centres were 'residential', as it was very likely that events were in people normally resident at those locations. I considered OHCA reported at NHS hospitals non-residential, as 999 calls made in those locations would only concern OHCA occurring in public areas. Details about in-hospital cardiac arrests attended by hospital cardiac arrest teams are not submitted to the OHCAO registry.

I had a list of public-access AED locations known to both LAS and EMAS (see **chapter 7** for more details). As I had an accurate OHCA location for the LAS dataset, I was able to calculate the straight-line distance from each OHCA incident to the nearest public-access AED. As I did not have precise OHCA location data for all EMAS OHCA (postcodes define a geographical area rather than a specific point) I could not determine this for the EMAS dataset.

Data from the OHCAO registry and GoodSAM were provided in spreadsheets. I manually matched GoodSAM alerts to confirmed OHCA, as described above, and collected the combined data in one spreadsheet. All data files were password protected. They were held either on a University of Warwick device with Windows 10 built-in encryption, which required a dedicated log-in to access, or on a secure University of Warwick file server encrypted with PGP encryption software (version 10.4, Symantec, Arizona, USA).

#### **6.3.4 Analysis and reporting of OHCA data**

The primary outcome measure was survival to hospital discharge, an important outcome for both researchers, patients and their families (13). I have presented and collected data according to the Utstein guidelines – an internationally recognised and standardised methodology for reporting OHCA that records 23 core elements across five domains (system, dispatch, patient, process, outcome) (9).

I used SPSS Statistics (version 26, IBM, New York, USA) for all statistical analyses. I assessed continuous data for normality using the Shapiro-Wilk test

and determined how much and in what direction the data was skewed from a normal distribution.

I have presented descriptive statistics as percentages and absolute numbers, and median (with interquartile range, IQR) values for continuous variables (age, ambulance response time and distance to nearest AED). I report the outcome and the other Utstein domain variables in cases when a GoodSAM alert was 'accepted', 'not seen or rejected', and when there was 'no alert' for both survival to hospital discharge and ROSC at hospital.

I constructed a multiple logistic regression model for both the LAS and EMAS data separately. The intention was to determine if there was an association between GoodSAM alert outcome and survival to hospital discharge after adjusting for these other relevant variables. I have presented both unadjusted odds ratios (OR) and an adjusted odds ratios (AOR) with 95% confidence intervals (95% CI).

Multicollinearity testing determines to what degree the independent variables in the logistic regression model correlate with each other, and is represented by the Variance Inflation Factor (VIF) and/or its reciprocal value 'tolerance'. For example, a VIF of 1.1 suggests that the variance shown by a variable within the model has been inflated by 10% because of interaction with other variables (305,306). A VIF of less than 4 or a tolerance of more than 0.25 is unlikely to substantially affect data analysis (306). Cox and Snell  $R^2$  and Nagelkerke  $R^2$  values indicate how much the predictor variables in the logistic regression model explain the outcome of interest: a value of 0 indicates that the predictor variables do not explain variance in the outcome variable at all and a value of 1 (for Nagelkerke  $R^2$ ; the maximum value in Cox and Snell  $R^2$  is not quite 1) indicates a perfect model where changes in the predictor variables in the model completely explain differences in the outcome measures. The Hosmer-Lemeshow Goodness of Fit test indicates how reliable the estimates provided for the outcome measure are (305).

The outcome (dependent) variable in the logistic regression model was survival to hospital discharge. The model contained the following (independent) variables, because of their potential to impact the outcome in OHCA: age (years), gender (male/female), OHCA witnessed status (by ambulance service, by bystander, unwitnessed), CPR performed (by ambulance service, by bystander, not performed), bystander AED use (yes/no, *LAS only*), location type (residential/non-residential), initial cardiac arrest rhythm (VF or VT/PEA/asystole), ambulance service response time (seconds), GoodSAM group (accepted/not seen or rejected/no alert) and distance to nearest AED (metres, *LAS only*). I entered all variables into the model for their potential to impact the outcome in OHCA. There was no statistical procedure to determine entry into the model. I adhered to the recommendation that there should be a minimum of ten events for the outcome of interest (here, those patients that survived to hospital discharge) for each predictor variable included in a logistic regression model (307).

### **6.3.5 Ethical approvals**

The Biomedical and Scientific Research Ethics Committee (BSREC) at the University of Warwick granted ethical approval on 6<sup>th</sup> March 2018 for collection and analysis of LAS data from the OHCAO registry and GoodSAM (reference: REGO 2018-2157). BSREC approved an amendment for collection and analysis of EMAS data on 29<sup>th</sup> October 2018 (REGO-2018-2157 AM01).

## **6.4 RESULTS**

### **6.4.1 OHCA incidence**

#### *London Ambulance Service*

There were 4448 OHCA reported to the OHCAO registry between 1<sup>st</sup> April 2016 – 31<sup>st</sup> March 2017. The GoodSAM reporting system was not operational from 30<sup>th</sup> August to 19<sup>th</sup> September 2016 and from 26<sup>th</sup> December to 30<sup>th</sup>

December 2016. There were 252 OHCA were reported during this time and so I present results from the remaining 4196 OHCAs.

### *East Midlands Ambulance Service*

There were 2281 OHCAs reported to the OHCAO registry between 18<sup>th</sup> June 2017 – 17<sup>th</sup> June 2018. I could only match OHCAs to GoodSAM alerts from 1<sup>st</sup> January – 17<sup>th</sup> June 2018, during which time there were 1041 OHCAs.

### **6.4.2 GoodSAM alerts**

Table 6.1 summarises the number of GoodSAM alerts and alert acceptances for both ambulance services in the respective study periods.

**Table 6.1: Description of GoodSAM alerts for OHCAs**

	<b>London Ambulance Service</b>	<b>East Midlands Ambulance Service</b>
<b>Total number of OHCAs</b>	4196	1041
<b>GoodSAM alert sent out</b>	6.7% (282/4196)	22% (227/1041)
<b>GoodSAM alert accepted</b>	1.3% (53/4196)	4.9% (51/1041)
<b>More than one GoodSAM responder accepted</b>	0.07% (3/4196 <sup>+</sup> )	0.3% (3/1041 <sup>+</sup> )

<sup>+</sup> Two GoodSAM responders accepted on each of these occasions

### *London Ambulance Service*

There were 11,894 emergency calls that fulfilled the criteria for a GoodSAM alert. GoodSAM sent out 1616 alerts for 1384 (11%) of these calls. There were 4196 cases subsequently confirmed as an OHCA (35% of 11,895 emergency calls fulfilling criteria for a GoodSAM alert). There were 354 alerts sent out for 282/4196 (6.7%) OHCAs. A GoodSAM responder accepted an alert on 56/354 (16%) occasions for 53 cases (1.3% of total 4196 OHCA cases), and the alert was 'not seen' or rejected on the remaining 298 occasions for 229 OHCAs.

In 56 cases there was more than one person who received an alert (2 people in 39 cases; 3 people in 14 cases; 4 people in 1 case; 5 people in 2 cases). There were three OHCA calls for which more than one person *accepted* the alert (two people in all three cases).

#### *East Midlands Ambulance Service*

There were 17,389 emergency calls that fulfilled the criteria for a GoodSAM alert between 18<sup>th</sup> June 2017 – 17<sup>th</sup> June 2018. GoodSAM sent out 10,039 alerts for 6362 (37%) of these calls. There were 2281 cases subsequently confirmed as OHCA (13% of all 17,389 emergency calls). For the 1041 confirmed OHCA (1<sup>st</sup> January – 18<sup>th</sup> June 2018), there were 349 alerts sent out for 227/1041 (22%) cases. An alert was accepted on 54/227 (24%) occasions for 51 cases (4.9% of 1041 OHCA cases); it was 'not seen' or rejected on the remaining 295 occasions for 176 OHCA.

In 73 cases there was more than one person who received an alert (2 people in 44 cases; 3 people in 20 cases; 4 people in 4 cases; 5 people in 1 case; 6 people in 2 cases; 7 people in 2 cases). There were three OHCA calls for which more than one person *accepted* the alert (two people in all three cases).

### **6.4.3 Patient and process variables**

#### *London Ambulance Service*

The median age of patients (n=4164, 32 unknown) was 69.3 (IQR 52.8-80.8) years and 64% (2695/4196) were male. The ambulance service witnessed 18% (739/4196) OHCA, bystanders 47% (1985/4196), and 35% (1472/4196) were unwitnessed.

Bystanders performed CPR in 53% (2211/4196) OHCA, or 64% (2209/3457) of the non-ambulance-service-witnessed cases. They attached an AED in 4.3% (179/4196) OHCA, or 5.1% (176/3457) of the non-ambulance-service-witnessed cases. 84% (3447/4111, 85 unknown) OHCA occurred in

residential locations. The median ambulance response time was 07:39 (IQR 05:45-10:24) minutes. The median distance to an AED (n=4111, 85 unknown) was 407 (IQR 222-642) metres. The initial cardiac rhythm (n=4172, 24 unknown) was VF/VT in 22% (916/4172), PEA in 28% (1179/4172) and asystole in 50% (2077/4172).

**Table 6.2** shows the breakdown by GoodSAM alert status.

#### *East Midlands Ambulance Service*

The median age of patients (n=1009, 32 unknown) was 72 (IQR 59-83) years and 63% (656/1041) were male. The ambulance service witnessed 2% (21/1041) OHCA, bystanders 54% (564/1041) and 44% (456/1041) were unwitnessed.

Bystanders performed CPR in 62% (647/1041) OHCA, or 63% (647/1020) of the non-ambulance service-witnessed cases. 84% (868/1033, 8 unknown) OHCA occurred in residential locations. The median ambulance service response time was 09:59 (IQR 06:16-16:02) minutes.

The initial cardiac rhythm (n=970, 71 unknown) was VF/VT in 18% (172/970), PEA in 21% (204/970) and asystole in 61% (594/970).

**Table 6.3** shows the breakdown by GoodSAM alert status.

**Table 6.2: Patient and process variables by GoodSAM response group (London)**

	GoodSAM Alert		No GoodSAM alert (n=3914)
	Accepted (n=53)	'Not Seen' or rejected (n=229)	
<b>Age (median (IQR), years)</b>	66.0 (50.0-77.1)	69.4 (54.0-80.0)	69.3 (52.7-80.9)
Unknown cases			32
<b>Gender</b>			
Male	64.2% (34/53)	67.2% (154/229)	64.1% (2507/3914)
Female	35.8% (19/53)	32.8% (75/229)	35.9% (1407/3914)
<b>OHCA witnessed by</b>			
EMS	3.8% (2/53)	2.2% (5/229)	18.6% (729/3914)
Bystander	58.4% (31/53)	60.7% (139/229)	46.4% (1815/3914)
Unwitnessed	37.8% (20/53)	37.1% (85/229)	35.0% (1367/3914)
<b>Bystander CPR</b>			
All cases	67.9% (36/53)	64.2% (147/229)	51.8% (2028/3914)
Non EMS-witnessed	70.6% (36/51)	65.6% (147/224)	63.7% (2026/3182)
<b>Bystander AED</b>			
All cases	9.4% (5/53)	8.3% (19/229)	4.0% (155/3913)
Non EMS-witnessed	9.8% (5/51)	8.5% (19/224)	4.8% (152/3182)
Unknown cases			1
<b>Location Type</b>			
Residential	69.8% (37/53)	72.0% (162/225)	84.7% (3248/3833)
Non-residential	30.2% (16/53)	28.0% (63/225)	15.3% (585/3833)
Unknown cases		4	81
<b>Initial Rhythm</b>			
VF/VT	20.8% (11/53)	29.3% (67/229)	21.5% (838/3890)
PEA	17.0% (9/53)	21.0% (48/229)	28.8% (1122/3890)
Asystole	62.3% (33/53)	49.8% (114/229)	49.6% (1930/3890)
Unknown cases			24
<b>EMS Response Time (median (IQR), mm:ss)</b>	06:21 (04:40-08:15)	06:41 (05:08-08:46)	07:45 (05:48-10:30)
<b>Distance from nearest AED (median (IQR), m)</b>	255 (134-433)	312 (140-539)	413 (228-651)
Unknown cases		5	82

**Table 6.3: Patient and process variables by GoodSAM response group  
(East Midlands)**

	GoodSAM Alert		No GoodSAM alert (n=814)
	Accepted (n=51)	'Not Seen' or rejected (n=176)	
<b>Age (median (IQR), years)</b>	73.0 (67.8-79.3)	70.0 (56.8-81.0)	72.0 (59.0-82.0)
Unknown cases	3	4	25
<b>Gender</b>			
Male	76.5% (39/51)	64.2% (113/176)	61.9% (504/814)
Female	23.5% (12/51)	35.8% (63/176)	38.1% (310/814)
<b>OHCA witnessed by</b>			
EMS	2.0% (1/51)	0.6% (1/176)	2.3% (19/814)
Bystander	49.0% (25/51)	51.1% (90/176)	55.2% (449/814)
Unwitnessed	49.0% (25/51)	48.3% (85/176)	42.5% (346/814)
<b>Bystander CPR</b>			
All cases	58.9% (30/51)	74.4% (131/176)	59.7% (486/814)
Non EMS-witnessed	60.0% (30/50)	74.9% (131/175)	61.1% (486/795)
<b>Location Type</b>			
Residential	80.4% (41/51)	86.4% (152/176)	83.7% (675/806)
Non-residential	19.6% (10/51)	13.6% (24/176)	16.3% (131/806)
Unknown cases			8
<b>Initial Rhythm</b>			
VF/VT	26.5% (13/49)	17.9% (30/168)	17.1% (129/753)
PEA	14.3% (7/49)	16.1% (27/168)	22.6% (170/753)
Asystole	59.2% (29/49)	66.1% (111/168)	60.3% (454/753)
Unknown cases	2	8	61
<b>EMS Response Time (median (IQR), mm:ss)</b>	07:59 (05:23-12:57)	07:29 (05:26-11:36)	10:46 (06:46-17:00)
Unknown cases		2	6

#### 6.4.4 OHCA outcomes

##### *London Ambulance Service*

Overall survival to hospital discharge was 9.6% (393/4111, 85 unknown), and ROSC at hospital was 29.1% (1219/4196). The breakdown by GoodSAM alert status is shown in **Table 6.4**.

**Table 6.4: Patient outcome by GoodSAM response group (London)**

	GoodSAM Alert		No GoodSAM alert (n=3914)
	Accepted (n=53)	'Not Seen' or rejected (n=229)	
<b>Survival to hospital discharge</b>	17.6% (9/51)	10.3% (23/223)	9.4% (361/3837)
Unknown cases	2	6	77
<b>ROSC at hospital</b>	39.6% (21/53)	28.4% (65/229)	28.9% (1133/3914)

*East Midlands Ambulance Service*

Overall survival to hospital discharge was 7.2% (72/1001, 40 unknown), and ROSC at hospital was 24.7% (257/1041). The breakdown by GoodSAM alert status is shown in **Table 6.5**.

**Table 6.5: Patient outcome by GoodSAM response group (East Midlands)**

	GoodSAM Alert		No GoodSAM alert (n=814)
	Accepted (n=51)	'Not Seen' or rejected (n=176)	
<b>Survival to hospital discharge</b>	15.2% (7/46)	5.3% (9/170)	7.1% (56/785)
Unknown cases	5	6	29
<b>ROSC at hospital</b>	25.5% (13/51)	23.3% (41/176)	24.9% (203/814)

**6.4.5 OHCA survival – logistic regression modelling**

*London Ambulance Service*

Survival to hospital discharge data were available in 4111 cases. Characteristics of survivors and non survivors are displayed in **Table 6.6**. Survivors were younger and there were markedly more survivors who had ROSC at hospital, ambulance-service-witnessed OHCA, public-location OHCA and VF/VT as the initial cardiac rhythm.

**Table 6.6: Characteristics of survivors and non-survivors from OHCA (London)**

	<b>Survived to Hospital Discharge (n=393)</b>	<b>Died (n=3718)</b>
<b>GoodSAM group</b>		
Accepted*	2.3% (9/393)	1.1% (42/3718)
Not Seen/Rejected	5.9% (23/393)	5.4% (200/3718)
No Alert	91.8% (361/393)	93.5% (3476/3718)
<b>ROSC at Hospital</b>		
Yes	94.7% (372/393)	21.3% (791/3718)
No	5.3% (21/393)	78.7% (2927/3718)
<b>Age (median (IQR), years)</b>	60.0 (49.4-71.9)	70.4 (53.8-81.7)
Unknown cases	4	24
<b>Gender</b>		
Male	73.0% (287/393)	63.0% (2339/3711)
Female	27.0% (106/393)	37.0% (1372/3711)
Unknown cases		7
<b>OHCA witnessed status</b>		
EMS	38.2% (150/393)	15.4% (573/3715)
Bystander	51.6% (203/393)	46.7% (1735/3715)
Unwitnessed	10.2% (40/393)	37.9% (1407/3715)
Unknown cases		3
<b>CPR performed by</b>		
EMS	38.2% (150/393)	15.4% (573/3718)
Bystander	47.3% (186/393)	53.1% (1975/3718)
Not performed	14.5% (57/393)	31.5% (1170/3718)
<b>Bystander AED</b>		
Yes	7.9% (31/393)	3.9% (145/3717)
No	92.1% (362/393)	96.1% (3572/3717)
Unknown cases		1
<b>Location type</b>		
Residential	68.0% (264/388)	86.0% (3129/3640)
Public	32.0% (124/388)	14.0% (511/3640)
Unknown cases	5	78
<b>Initial Rhythm</b>		
VF/VT	75.8% (294/388)	16.0% (590/3699)
PEA	16.5% (64/388)	29.4% (1089/3699)
Asystole	7.7% (30/388)	54.6% (2020/3699)
Unknown cases	5	19
<b>EMS Response Time (median (IQR), mm:ss)</b>	07:32 (05:29-09:36)	07:41 (05:46-10:28)
<b>Distance from nearest AED (median (IQR), m)</b>	389 (197-598)	409 (226-648)
Unknown cases	5	78

The continuous variables of age, ambulance service response time and distance from nearest AED were all non-normally distributed (Shapiro-Wilk test for normality all  $p < 0.001$ ). There was a positive skew for ambulance service response time (more values at shorter response times: Skewness +8.62) and distance from nearest AED (more values at closer distances: Skewness +1.88) and a negative skew for age (more values at older ages: Skewness -0.880).

Tests for multicollinearity suggest that there was little correlation between the independent values tested: variance inflation factors (VIF) were all less than 1.22 (**Table 6.7**).

**Table 6.7: Multicollinearity table for independent variables included in the logistic regression model (London)**

	Collinearity Statistics	
	Tolerance	VIF
<b>GoodSAM Group</b>	.981	1.020
<b>Age in Years</b>	.928	1.078
<b>Gender</b>	.950	1.053
<b>OHCA Witnessed status</b>	.896	1.116
<b>CPR performed by</b>	.952	1.051
<b>Bystander AED performed</b>	.907	1.103
<b>Location Type</b>	.821	1.218
<b>Initial Rhythm</b>	.851	1.175
<b>EMS Response Time in Seconds</b>	.988	1.012
<b>Distance to nearest AED</b>	.958	1.044

I constructed a logistic regression model using these variables, ultimately including data from 3971/4196 (94.6%) OHCA's.

Cox & Snell  $R^2$  (0.185) and Nagelkerke  $R^2$  (0.395) suggest that 18.5-39.5% of the variation in survival to hospital discharge can be explained by this model. The p-value for the Hosmer-Lemeshow Goodness of Fit test was non-significant (0.239), suggesting overall goodness of fit.

The AOR for survival to hospital discharge if a GoodSAM alert was accepted (compared to no alert being sent) was 3.15 (95% CI 1.19-8.36; p=0.021). If the GoodSAM alert 'not seen or rejected' was taken as the reference, the AOR for survival to hospital discharge in the GoodSAM alert accepted group was 3.06 (95% CI 1.03-9.03; p=0.04). The unadjusted ORs and AORs for all variables in the model are presented in **Table 6.8**.

**Table 6.8: Logistic regression model. Adjusted odds ratios (AOR) for survival to hospital discharge (London)**

	Unadjusted OR (95% CI)	AOR (95% CI)
<b>GoodSAM group</b>		
Accepted	2.06 (0.99-4.27); p=0.052	<b>3.15 (1.19-8.36); p=0.021</b>
Not seen/rejected	1.11 (0.71-1.73); p=0.66	1.03 (0.61-1.75); p=0.908
No alert	Reference	Reference
<b>EMS response time</b>	1.00 (0.99-1.99); p=0.011	<b>0.99 (0.99-1.00); p=0.005</b>
<b>Age in years</b>	0.99 (0.98-0.99); p<0.001	<b>0.98 (0.97-0.98); p&lt;0.001</b>
<b>Gender</b>		
Male	1.59 (1.26-2.00); p<0.001	0.97 (0.73-1.30); p=0.844
Female	Reference	Reference
<b>OHCA witnessed status</b>		
EMS	9.21 (6.41-13.2); p<0.001	<b>7.70 (4.76-12.5); p&lt;0.001</b>
Bystander	4.12 (2.91-5.82); p<0.001	<b>1.84 (1.25-2.71); p=0.002</b>
Unwitnessed	Reference	Reference
<b>CPR performed by</b>		
EMS	5.37 (3.90-7.41); p<0.001	<i>Not calculated*</i>
Bystander	1.93 (1.42-2.62); p<0.001	1.09 (0.77-1.56); p=0.621
Not performed	Reference	Reference
<b>Bystander AED</b>		
Yes	2.11 (1.41-3.16); p<0.001	1.38 (0.82-2.33); p=0.227
No	Reference	Reference
<b>Initial rhythm</b>		
VF/VT	33.6 (22.8-49.4); p<0.001	<b>27.9 (18.4-42.3); p&lt;0.001</b>
PEA	3.96 (2.55-6.14); p<0.001	<b>2.42 (1.51-3.90); p&lt;0.001</b>
Asystole	Reference	Reference
<b>Location type</b>		
Non-residential	2.88 (2.28-3.63); p<0.001	<b>1.66 (1.23-2.25); p=0.001</b>
Residential	Reference	Reference
<b>Distance from nearest AED</b>	1.00 (0.99-1.00); p=0.13	1.00 (1.00-1.00); p=0.35

\*EMS performed CPR for all of the cases that were EMS-witnessed, therefore not calculated by SPSS (redundancy)

Survival to hospital discharge data were available in 1001 cases. Characteristics of survivors and non survivors are displayed in **Table 6.9**. Survivors were younger and there were markedly more survivors who had ROSC at hospital, public-location OHCA and VF/VT as the initial cardiac rhythm.

**Table 6.9: Characteristics of survivors and non-survivors from OHCA (East Midlands)**

	Survived to Hospital Discharge (n=72)	Died (n=929)
<b>GoodSAM group</b>		
Accepted*	9.7% (7/72)	4.2% (39/929)
Not Seen/Rejected	12.5% (9/72)	17.3% (161/929)
No Alert	77.8% (56/72)	78.5% (729/929)
<b>ROSC at Hospital</b>		
Yes	79.2% (57/72)	18.8% (175/929)
No	20.8% (15/72)	81.2% (754/929)
<b>Age (median (IQR), years)</b>	55.0 (44.8-70.3)	73.0 (60.0-82.0)
Unknown cases		12
<b>Gender</b>		
Male	73.6% (53/72)	61.4% (570/929)
Female	26.4% (19/72)	38.6% (359/929)
<b>OHCA witnessed status</b>		
EMS	1.4% (1/72)	2.0% (19/929)
Bystander	69.4% (50/72)	52.5% (488/929)
Unwitnessed	29.2% (21/72)	45.5% (422/929)
<b>CPR performed by</b>		
EMS	1.4% (1/72)	2.0% (19/929)
Bystander	58.3% (42/72)	61.9% (575/929)
Not performed	40.3% (29/72)	36.1% (335/929)
<b>Location type</b>		
Residential	68.6% (48/70)	87.3% (806/923)
Public	31.4% (22/70)	12.7% (117/923)
Unknown cases	2	6
<b>Initial Rhythm</b>		
VF/VT	57.1% (36/63)	13.8% (121/874)
PEA	20.6% (13/63)	21.2% (185/874)
Asystole	22.3% (14/63)	65.0% (568/874)
Unknown cases	9	55
<b>EMS Response Time (median (IQR), mm:ss)</b>	08:54 (05:33-15:09)	10:06 (06:19-16:07)
Unknown cases	2	6

The continuous variables of age and ambulance service response time were both non-normally distributed (Shapiro-Wilk test for normality, both  $p < 0.001$ ). There was a positive skew for ambulance service response time (more values at shorter response times: Skewness +4.96) and a negative skew for age (more values at older ages: Skewness -1.25).

Tests for multicollinearity suggest that there was little correlation between the independent values tested: variance inflation factors (VIF) were all less than 1.07 (**Table 6.10**).

**Table 6.10: Multicollinearity table for independent variables included in the logistic regression model (East Midlands)**

	Collinearity Statistics	
	Tolerance	VIF
<b>GoodSAM Group</b>	.969	1.032
<b>Age in Years</b>	.949	1.054
<b>Gender</b>	.957	1.045
<b>OHCA Witnessed Status</b>	.940	1.064
<b>CPR performed by</b>	.972	1.029
<b>Location Type</b>	.941	1.063
<b>Initial Rhythm</b>	.939	1.065
<b>EMS Response Time in Seconds</b>	.955	1.048

I constructed a logistic regression model using these variables, ultimately including data from 907/1041 (87.1%) cases.

Cox & Snell  $R^2$  (0.109) and Nagelkerke  $R^2$  (0.286) suggest that 10.9-28.6% of the variation in survival to hospital discharge can be explained by this model. The p-value for the Hosmer-Lemeshow Goodness of Fit test was non-significant (0.600), suggesting overall goodness of fit.

The AOR for survival to hospital discharge if a GoodSAM alert was accepted (compared to no alert being sent) was 3.19 (95% CI 1.17-8.73;  $p=0.024$ ). If the GoodSAM alert 'not seen or rejected' was taken as the reference, the AOR for survival to hospital discharge in the GoodSAM alert accepted group was 4.84

(95% CI 1.34-17.5; p=0.016). The unadjusted ORs and AORs for all variables in the model are presented in **Table 6.11**.

**Table 6.11: Logistic regression model. Adjusted odds ratios (AOR) for survival to hospital discharge (East Midlands)**

	Unadjusted OR (95% CI)	AOR (95% CI)
<b>GoodSAM group</b>		
Accepted	2.34 (1.00-5.46); p=0.05	<b>3.19 (1.17-8.73); p=0.024</b>
Not seen/rejected	0.73 (0.35-1.50); p=0.39	0.66 (0.26-1.77); p=0.378
No alert	Reference	Reference
<b>EMS response time</b>	1.00 (1.00-1.00); p=0.97	1.00 (1.00-1.00); p=0.818
<b>Age in years</b>	0.96 (0.95-0.97); p<0.001	<b>0.96 (0.94-0.97); p&lt;0.001</b>
<b>Gender</b>		
Male	1.76 (1.02-3.02); p=0.041	1.29 (0.65-2.52); p=0.467
Female	Reference	Reference
<b>OHCA witnessed status</b>		
EMS	1.06 (0.14-8.28); p=0.96	1.37 (0.15-12.3); p=0.778
Bystander	2.06 (1.22-3.48); p=0.007	<b>2.13 (1.09-4.15); p=0.028</b>
Unwitnessed	Reference	Reference
<b>CPR performed by</b>		
EMS	0.61 (0.08-4.71); p=0.63	<i>Not calculated*</i>
Bystander	0.84 (0.52-1.38); p=0.84	0.73 (0.39-1.41); p=0.350
Not performed	Reference	Reference
<b>Initial rhythm</b>		
VF/VT	12.1 (6.32-23.1); p<0.001	<b>10.7 (5.09-22.3); p&lt;0.001</b>
PEA	2.85 (1.32-6.18); p=0.008	<b>3.94 (1.66-9.37); p=0.002</b>
Asystole	Reference	Reference
<b>Location type</b>		
Non-residential	3.16 (1.84-5.42); p<0.001	1.73 (0.87-3.44); p=0.121
Residential	Reference	Reference

\*EMS performed CPR for all of the cases that were EMS-witnessed, therefore not calculated by SPSS (redundancy)

## 6.5 DISCUSSION

### 6.5.1 Main findings

Acceptance of a GoodSAM alert was associated with improved survival to hospital discharge in a 12-month period in London, and in a 6-month period in East Midlands. The odds for this improved survival were statistically significant

following logistic regression analyses, although the numbers of accepted alerts was small. The study periods started five months (LAS) and six months (EMAS) after the full roll-out of GoodSAM in the study areas.

A smaller proportion of emergency calls in East Midlands (13%) than in London (35%) resulted in GoodSAM alerts that were actually confirmed OHCAs. Overall, the proportion of alerts that GoodSAM responders accepted was low, but slightly higher in East Midlands (4.9%) than in London (1.3%).

Other notable differences were substantially more ambulance service witnessed OHCAs in LAS (18% vs 2%), a shorter ambulance service response time (median 07:39 vs 09:58 mins) and higher VF/VT rates (22% vs 18%).

### **6.5.2 Comparison with the literature**

Overall survival to discharge in this study was 9.6% in London (2016-17) and 7.2% in East Midlands (2018). This compares to survival to hospital discharge figures from the OHCAO registry of 7.3% in 2016 (nine English ambulance services (308)), 8.1% in 2017 (nine English ambulance services (309)) and 9.3% in 2018 (all ten English ambulance services (12)). Crude survival rates in the small number of patients for whom a GoodSAM responder accepted an alert were 18% (London) and 15% (East Midlands).

I reported survival to hospital discharge. This is an important clinical outcome that clinicians, patients and their relatives all believe should be consistently reported in OHCA studies (13). Two observational studies reported improved survival to hospital discharge when volunteer first-responders were activated (163) or attended an OHCA patient (164). The authors of both these studies attempted to account for confounders, by propensity score matching (163) or by multiple logistic regression (164), but neither accounted for the impact of bystander AED use.

A 2019 Cochrane Library systematic review (159) found only one RCT (162) evaluating the effect of volunteer first-responder systems. This study, of 676

non-traumatic OHCA in patients aged eight years and older, found no improvement in 30-day survival when patients received a supplementary response from volunteer first-responders within a 500m radius, compared to a standard ambulance service response alone (OR 1.34, 95% CI 0.79-2.29). However, the study was not powered for this outcome and did not mention public-access AED use.

Volunteer first-responder systems increase rates of CPR and defibrillation performed before the ambulance service arrive (162,164,170), but outcomes in patients for whom volunteer first-responders started CPR may be no higher than when other bystanders started CPR (163). In this study I did not have the data to determine which interventions GoodSAM responders performed following alert acceptance.

### **6.5.3 Strengths and limitations**

This study provides a snapshot of GoodSAM use in London and East Midlands, starting a similar length of time after both ambulance services integrated GoodSAM with their systems. I have highlighted important differences between the two ambulance services regarding the number and proportion of alerts sent out and accepted.

I collected ROSC at hospital, but ultimately decided not to include this in the logistic regression model. ROSC itself is an outcome that could be directly influenced by a GoodSAM response. It is already known to be the biggest predictor of survival to hospital discharge (34). There is also consensus that survival to hospital discharge, favourable neurological outcome and functional performance post OHCA are the most relevant outcome measures (13).

#### *Data quality*

I was able to collect data on all-cause OHCA from the OHCAO registry, but I was restrained in some respects by limitations of the data that ambulance services submitted to the registry. For example, EMAS did not submit data on

bystander AED use. Neither ambulance service provided data on public-access AED availability (although a data field does exist in the OHCAO registry) in cases when a bystander did not retrieve an AED.

GoodSAM provided date, time and incident location for all incidents that met GoodSAM activation criteria. The OHCAO registry and GoodSAM databases had different identifying numbers for incidents, so I had to match a GoodSAM alert to an OHCA manually. As there were often several GoodSAM alerts within a few minutes of a recorded OHCA, I could only accurately make a match by comparing incident locations in both databases. For EMAS, a lack of accurate location data meant that I could only analyse six months' data (January – June 2018, when location data was supplemented by full postcode from the OHCAO registry) rather than the twelve months' data (June 2017 – June 2018) that I originally planned.

Another concern is that there were no data to determine whether or not a GoodSAM responder reached the patient after accepting an alert. I cannot comment on which interventions they performed, how often they did so, or if they arrived before the ambulance service.

There were other occasions where I had to make decisions about the data. The LAS dataset did not indicate 'residential' or 'non-residential' location, and the EMAS dataset provided multiple definitions of location type as per the Utstein guidelines (9). I dichotomised these manually. I decided that care homes and community hospitals would be 'residential' but other researchers may disagree.

There was the possibility for misclassification of some GoodSAM alerts. It is possible that some people would respond to a nearby alert without indicating acceptance on the app (for example, the alert siren sounds on the app, a commotion is visible a very short distance away and the GoodSAM responder prioritises going to scene rather than opening up the app). Some GoodSAM responders will be ambulance service employees and may receive an alert on

their personal mobile phones whilst already responding to the alert in a professional capacity.

### *Sources of bias*

With this type of study there is a risk of confounding by indication. Are the patients who are more likely to survive, by nature of some factor that we have not been able to account for, more likely to get a GoodSAM response in the first place? For example, I did not have access to data about GoodSAM responder density, patient ethnicity or co-morbidity, or specific neighbourhood characteristics. Time of day might affect the likelihood of a GoodSAM alert acceptance but I did not analyse this.

Ambulance services submit data to the OHCAO registry about OHCA where they start or continue resuscitation efforts. There is a possibility that an ambulance service might not classify cases where successful resuscitation occurs before the ambulance service arrives – for example, following very prompt bystander public-access AED use – as an OHCA. If ambulance service staff perform CPR briefly on someone who loses consciousness but did not actually lose cardiac output (for example, bradyarrhythmias causing brief hypoperfusion of the brain), this case might erroneously be classified as a successfully-resuscitated OHCA and submitted to the OHCAO registry.

There were little missing outcome data. I was able to ascertain survival to hospital discharge for 4111/4196 (98%) LAS cases and 1001/1041 (96%) EMAS cases. Missing data from independent variables, notably initial cardiac rhythm, meant that I performed logistic regression analysis on 3971/4196 (97%) LAS cases and 907/1041 (87%) EMAS cases. A reasonable hypothesis would be that cases in which death occurred before arrival at hospital would prove more difficult to gather data on, but in fact the survival rate was similar in the cases included in the logistic regression analysis compared to overall (9.5% vs 9.6% LAS and 6.5% vs 7.2% EMAS).

### *Logistic regression model*

Non-significant values for the Hosmer-Lemeshow goodness of fit test ( $p=0.24$  LAS and  $p=0.6$  EMAS) indicate broad support for the models. However, Cox & Snell  $R^2$  and the Nagelkerke  $R^2$  estimates suggests that only 19-40% of the variability in outcome is explained by the LAS model, and 11-29% of the variability in outcome is explained by the EMAS model. VIF and tolerance values close to 1 in both LAS and EMAS models suggest that multicollinearity is not a problem that is skewing the results of the regression (305,306).

I reported on all-cause OHCA as this is the best measure of utility in a system where information on cardiac rhythm and OHCA aetiology are not available at the time of an alert. This makes direct comparisons between two ambulance service regions difficult. In addition, the time periods for data collection were different and non-overlapping, and the duration of data collection was different. For all of these reasons I produced separate logistic regression models for each ambulance service rather than combining data.

#### **6.5.4 Clinical implications**

This study suggests an independent association between a GoodSAM responder accepting an alert and improved survival to hospital discharge. The magnitude of the effect was similar in two different datasets from two different ambulance services. However, this is observational data and it is unlikely that this study has accounted for all confounding factors. The wide confidence intervals suggest imprecise results, likely because there were very few GoodSAM alerts accepted. I could also not directly report which interventions GoodSAM responders performed on-scene.

The effect of imprecision, indirectness and risk of bias mean that this study likely represents a very low certainty of evidence according to the GRADE (Grading of Recommendations, Assessment, Development and Evaluations) framework (209): i.e. the true effect might be different to the effect estimated in this study. It is plausible that improvement in survival brought about by a

GoodSAM response is due to increased and earlier provision of CPR and/or defibrillation, but it is not clear whether this approach is superior to strategies to improve the provision of timely bystander CPR and public-access AED use. Set-up and maintenance costs of using GoodSAM in the response to OHCA are modest (174), so pursuing strategies to improve both volunteer first-responder and bystander-provided interventions is reasonable.

There is supporting evidence for the benefits of volunteer first-responder systems from other observational studies (163,164) subject to similar biases, but no overall benefit from the one RCT evaluating volunteer first-responders (162) – albeit this was not powered to detect a difference in survival to hospital discharge.

How ambulances services implement the GoodSAM app in the complex and unpredictable out-of-hospital environment is at least as important as the intervention itself. Optimising the GoodSAM response requires an understanding of the behaviours of the responders using it.

There are a number of issues that remain following this study. We could more directly assess the impact of GoodSAM if data collection about on-scene interventions was more reliable. I have made further efforts in this regard in **chapter 10**. GoodSAM now uses Global Positioning System (GPS) proximity to an OHCA event to determine if a GoodSAM responder arrived on scene. The previous reliance (at the time of the two study periods in this chapter) on a responder pressing a button to indicate arrival on scene meant that I could not be sure from the data that had whether they had reached the scene and not pressed the relevant button, or simply not arrived.

Alert acceptance rates were low, and there were very few alerts where multiple responders accepted. This substantially limits opportunities to send some responders directly to the patient and some to retrieve a public-access AED – a strategy that is currently employed and being evaluated in the ‘Heartrunner’ volunteer first-responder system in Denmark and Sweden (183).

EMAS notified GoodSAM responders up to (a radius of) 800m away; LAS only 300m. In both ambulance services alert acceptance as a proportion of alerts sent for confirmed OHCA was similar (16% LAS vs 15% EMAS). It is not clear if or how an increased alert radius in EMAS affects a GoodSAM responder's decision to accept an alert. GoodSAM do not routinely record responders' travel distance. There are likely to be a number of other factors affecting someone's decision to accept or reject an alert that I have not explored in this chapter.

An international survey reported that the minimal clinically important difference in survival to hospital discharge that would change practice (in a population with a baseline 25% survival) was 5% ([310](#)). The point estimates of effect size reported (AOR of 3.19 for LAS and 3.15 for EMAS) in this study (with overall survival of 9.6% and 7.2%, respectively) are likely to be clinically relevant. Therefore, it is important that researchers attempt to gather evidence that provides a higher certainty that this effect is real.

Researchers should only consider GoodSAM as one part of a wider strategy to improve bystander intervention and clinical outcomes. In this study, few GoodSAM alerts were for actual OHCA, and this figure was lower in EMAS where the response radius was larger. Contrastingly, if an OHCA diagnosis is not made, a GoodSAM alert is not made at all. Improving both sensitivity and specificity of OHCA diagnosis by dispatchers increases the likelihood of using GoodSAM effectively.

Improving the community response to OHCA might also include widespread training ([311](#)), particularly of school-age children ([107](#)), maintaining a registry of public-access AEDs ([109](#)) that is available to ambulance service dispatchers and members of the public, and optimising placement and accessibility of public-access AEDs ([178,179,181](#)).

### **6.5.5 Next steps**

I will present and publish work presented in this chapter. I will disseminate, via GoodSAM, to national ambulance services and to patient advocate groups in London and East Midlands.

In **chapters 8 and 9** I have reported the use of behaviour change methodologies to address one aspect of the GoodSAM response (public-access AED use), but a theoretically-informed approach could be applied to all aspects of all volunteer first-responder systems to get the most benefit from their use.

In **chapter 10** I have investigated the optimal response radius for GoodSAM responders, and characterised further the actions of GoodSAM responders following acceptance of an alert. In response to low numbers of alerts accepted in this chapter, GoodSAM decided to increase the alerting radius in London from 300m to 400m (for Tier 3 responders) or 700m (for Tier 1 and 2 responders). I have also examined the effect of this in **chapter 10**.

## **6.6 CONCLUSION**

Acceptance of a GoodSAM alert was associated with improved survival to hospital discharge in the time periods studied, in both ambulance service regions. Alert acceptance rates were low. Opportunities remain to increase the number of GoodSAM responders who accept an alert, and to strengthen data collection regarding interventions that GoodSAM responders provide to OHCA patients.

# CHAPTER 7

The potential for bystander public-  
access Automated External  
Defibrillator use in out-of-hospital  
cardiac arrest

---

The maps displayed in this chapter are either 'OS Vector Map District' (for small- and mid-scales) or 'OS Open Map Local' (for larger scales). The ArcGIS programme in which the maps were generated automatically changes the basemap based on the scale.

Both of these maps are available under the 'Open Data' licence from Ordnance Survey, which are covered by the Open Government Licence (OGL) <http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/>. This allows for copying and distribution of the data, with the following attribution statement:

**Contains OS data © Crown copyright and database right (2019)**

---

## 7.1 INTRODUCTION

Early defibrillation of a fibrillating heart in out-of-hospital cardiac arrest (OHCA) is an important part of improving survival, but this is likely to be most effective if delivered within the first three to five minutes following a patient's collapse (6). In many cases, such prompt defibrillation may only be possible by members of the public retrieving and using public-access Automated External Defibrillators (AEDs) before the ambulance service arrives.

Estimates about the effective coverage area of a public-access AED – the maximum distance from an AED that an OHCA can occur for its retrieval to impact outcome – vary. Studies suggest distances up to 100m (176,178) and 500m (168). Data from English ambulance services demonstrated that they had an 'operational AED retrieval radius' (distance from an OHCA within which they would ask a bystander to retrieve an AED) between 100-600m (276). The Resuscitation Council UK recommend that when an organisation or community obtains an AED, it should be placed so that it is accessible within a 2 minute "brisk walk" (125). This would be 200m at a speed of 100m/minute, previously defined as a brisk walk in a study from the south of England (276).

However, using radius or straight-line distance does not reflect the actual travel route using roads and other paths and may result in an overestimate of AED coverage (276). In Hong Kong, calculating walking distance rather than

straight-line distance increased the average distance from an OHCA to the nearest AED from 231m to 545m, and reduced the proportion of AEDs within 100m of historical OHCA from 30% to 11% (277). In Italy, the geographical area (in square metres, m<sup>2</sup>) that an AED covered was similar if comparing a 200m walking distance with a 100m radius (312). Travel modality and speed also potentially affect an AED's effective coverage area – if you can travel faster (e.g. by bike or car, compared to walking) then you can travel farther to retrieve an AED in the same time.

Public-access AED use is an option for GoodSAM responders who are alerted to a nearby OHCA, as well as bystanders at the scene of an OHCA. The distribution and proximity of an AED to both GoodSAM responder and the OHCA patient may be a factor that influences its retrieval: bystander AED use may decrease rapidly as the AED's distance from an OHCA patient increases (280) (282). The magnitude of the difference between straight-line and real-world travel distance, and the corresponding additional time to AED retrieval, may be important considerations for GoodSAM responders during an alert, and for bystanders or ambulance service dispatchers during a 999 call.

## **7.2 AIM**

The aim in this chapter was to compare the straight-line and real-world travel distance to the nearest public-access AED for historical OHCA in London and East Midlands.

## **7.3 METHODS**

### **7.3.1 Data sources**

I signed a formal data sharing arrangement with the Out-of-Hospital Cardiac Arrest Outcomes (OHCAO) registry at the University of Warwick on 23<sup>rd</sup> April 2018 for OHCA data from London Ambulance Service (LAS) between 1<sup>st</sup> April 2016 – 30<sup>th</sup> March 2017, and on 6<sup>th</sup> February 2019 for OHCA data from East Midlands Ambulance Service (EMAS) between 18<sup>th</sup> June 2017 – 17<sup>th</sup> June

2018. This included OHCA location, which LAS provided as address and postcode and EMAS provided as per Utstein definition (e.g. residential, public building, street, workplace) only (9). For a number of the EMAS OHCAOs, the OHCAO registry provided a full postcode.

The University of Warwick (on my behalf) signed a data-sharing arrangement with GoodSAM on 12<sup>th</sup> December 2017. GoodSAM records the incident location for its alerts as longitude and latitude. As described in **chapter 6**, I used date, time and location of an incident to match GoodSAM alerts to confirmed OHCAOs.

The University of Warwick (on my behalf) signed a data-sharing arrangement with LAS on 13<sup>th</sup> December 2017 for access to the location of public-access AEDs registered with them. The location of public-access AEDs known to EMAS was published online on 28<sup>th</sup> February 2019 after a Freedom of Information request (by an individual not connected with this project) ([https://www.whatdotheyknow.com/request/public\\_access\\_defibrillator\\_location](https://www.whatdotheyknow.com/request/public_access_defibrillator_location) 5). I confirmed the validity of this list with EMAS by e-mail on 17<sup>th</sup> September 2019. Both LAS and EMAS provided AED location as address and Eastings/Northings, and the list of public-access AEDs provided by both ambulance services included those in buildings that might not be accessible at all times of the day.

### **7.3.2 Mapping OHCA and public-access AED locations**

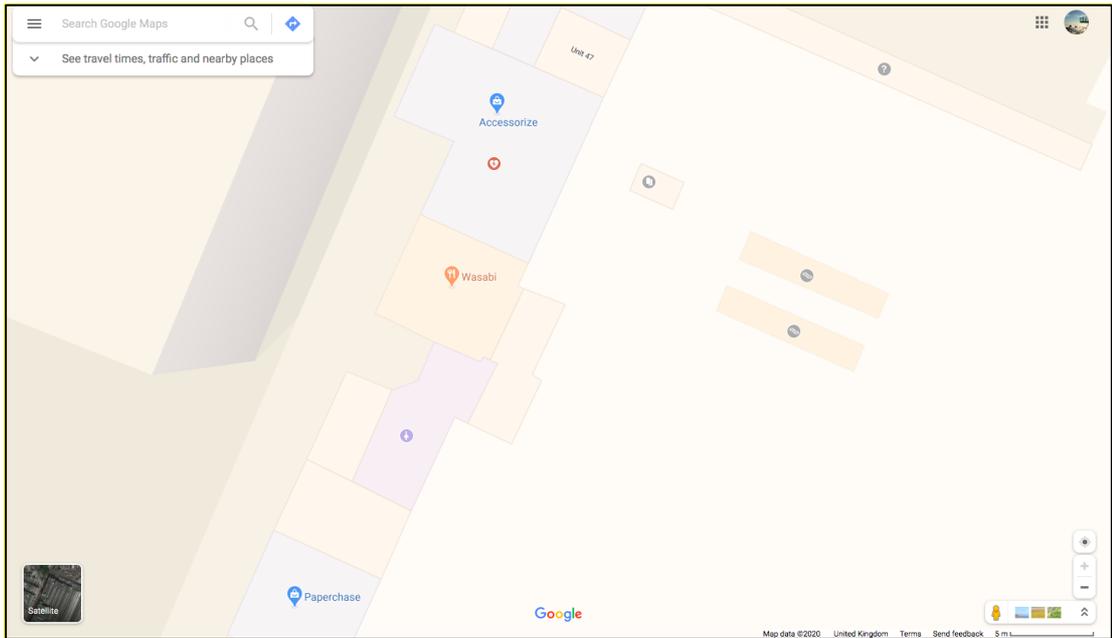
I conducted all mapping using the ArcGIS (version 10.5.1, ESRI, California, USA) Geographical Information Systems (GIS) software package. I used the 'OS Open Carto' (Ordnance Survey Limited, Southampton, UK) as a 'basemap' (background map). This map provides coverage for Great Britain and uses the British National Grid as its coordinate system. This is a 'Projected Coordinate System' (spherical coordinates are transformed to a 'planar' or flat/two-dimensional map). Coordinates are presented as six-digit 'Eastings' (x-coordinate) and 'Northings' (y-coordinate), which is accurate to a one-metre square. Geographic Co-ordinate Systems are based on a spherical earth

projection, and use latitude and longitude as coordinates. If a location's latitude and longitude are overlaid on a map using a Projected Coordinate System without first being converted to Eastings/Northings or subject to a mathematical transformation then its position will be incorrect (313).

Thus, where I had an address and postcode, or latitude and longitude of an OHCA, I converted this to Eastings/Northings using a freely available Batch Geocoder (UK Grid Reference Finder Batch Convert Tool: <https://gridreferencefinder.com/batchConvert/batchConvert.php>). I mapped a random selection of Eastings/Northings on that website and compared them to the original address, postcode or latitude/longitude to confirm that the locations mapped were indeed the same.

For the London dataset, there were sometimes large sites with multiple AEDs (for example, transport hubs and large sporting or entertainment arenas) registered with the same Easting/Northing for all devices. I was able to improve the accuracy of this in a number of ways:

- Combining description of the location (also provided by LAS) with images from Google Maps and Streetview (Google LLC, California, USA). On a number of occasions Google Maps displayed floorplans for larger buildings, and had AED locations marked on it (**Figure 7.1** provides an example). I obtained a latitude/longitude from Google Maps and converted it to an Easting/Northing
- Visits to London. I travelled around a number of sites in London to find an accurate location for a number of AEDs and visually inspect an AED location
- Where visual inspection was not possible because of restricted access (e.g. airport terminals) I was able to use the GoodSAM app on my mobile phone when I was close to the location of interest: GoodSAM displays the location of AEDs near to your location, and has reciprocal sharing of its AED database with LAS (**Figure 7.2** for example)



**Figure 7.1: An example of an AED location displayed on Google Maps at London Victoria Rail Station (in 'Accessorize')**



**Figure 7.2: The GoodSAM app, displaying the location of nearby AEDs**

The East Midlands dataset had unique locations for each individual AED.

I created separate spreadsheets in Microsoft Excel (Microsoft Corporation, Washington, USA) with Eastings and Northings of both OHCA and AEDs, for LAS and EMAS datasets. I created a 'Feature Class' from this table in ArcGIS and applied the British National Grid co-ordinate system in order to match the co-ordinate system of the basemap. These geolocated data are saved as a 'Shapefile' and can be overlaid on the basemap, thus displaying OHCA and/or AED locations (as points/icons).

Where I have presented visual displays of OHCA and AED locations, these have been done at a scale and level of detail that precludes identification of an individual location.

### **7.3.3 Spatial and data analysis**

#### *Calculating straight-line distance from an OHCA to the nearest AED*

Using the 'Near' tool in ArcGIS, I assigned OHCA as the 'input feature' and AEDs as the 'near' feature. ArcGIS created a data table identifying the nearest AED to each OHCA, and provided the distance in metres. I calculated the 'planar' distance between points, which does not take account of the curvature of the earth.

#### *Calculating real-world travel distance from an OHCA to the nearest AED*

This required the creation of a 'network' of lines (i.e. roads and paths) that could be overlaid on the basemap. The basemap is a 'Raster' map – this is essentially a large pixelated image displaying roads, paths and other map features. It is not something that one can plot routes along (314). To achieve this, I downloaded 'OS Open Local' Vector maps (<https://www.ordnancesurvey.co.uk/opendatadownload/products.html>) for the relevant areas of the UK. These Vector maps have 'roads' and 'road tunnels' as 'vector' features – they are lines that can be overlaid, by applying the same

coordinate system (British National Grid) to the Raster basemap. I used ArcGIS to create a network from these vector features, which allows one to model travel along them. For this study, I placed no restrictions on the network (e.g. there were no roads that could only be travelled along in one direction only, or no turns that were not permitted). Once I had created the network I used the 'Closest Facilities' function of the 'Network Analyst' tool in ArcGIS – allocating the already-uploaded OHCA as 'incidents' and AEDs as 'facilities' – to determine the road/path travel distance (in metres) from each OHCA to its nearest AED.

Each AED may be the closest device to more than one historical OHCA, or indeed none. This would indicate an element of clustering in each AED device in terms of the OHCA. However, there has been no analysis of whether or not a particular AED was or was not used in the OHCA response, so it was not relevant to use statistical techniques that account for clustering of OHCA around particular AEDs.

Data from **chapter 6** suggest the distance to the nearest AED is not normally distributed, so I presented distances as median with interquartile range (IQR). I used the related sample Wilcoxon Signed Ranks test to compare the median of differences between straight-line and real-world travel distances for both LAS and EMAS data.

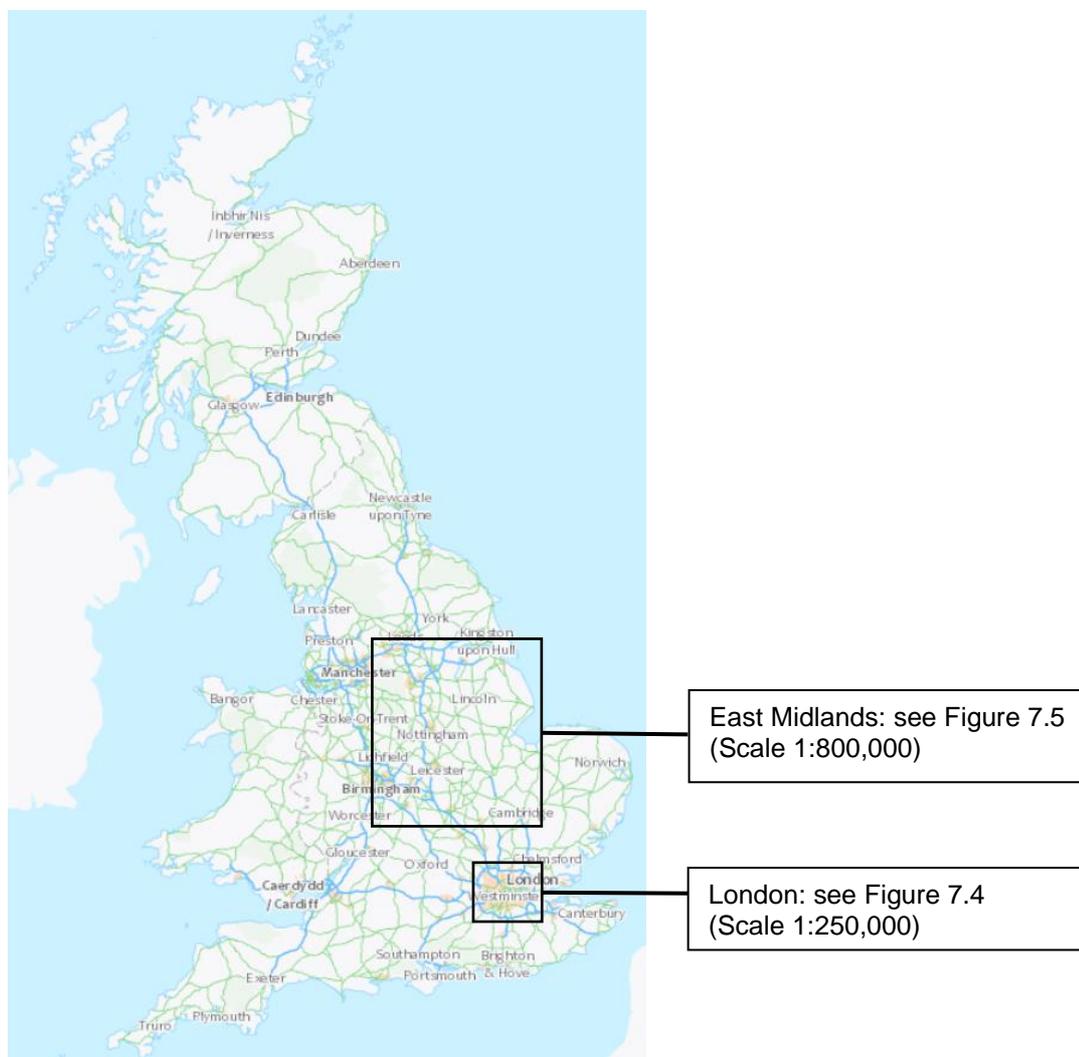
#### **7.3.4 Ethical approvals**

The Biomedical and Scientific Research Ethics Committee (BSREC) at the University of Warwick (reference: REGO 2018-2157) granted ethical approval on 6<sup>th</sup> March 2018 for collection and analysis of LAS data from GoodSAM and the OHCAO registry. BSREC approved an amendment for collection and analysis of EMAS data on 29<sup>th</sup> October 2018 (REGO-2018-2157 AM01).

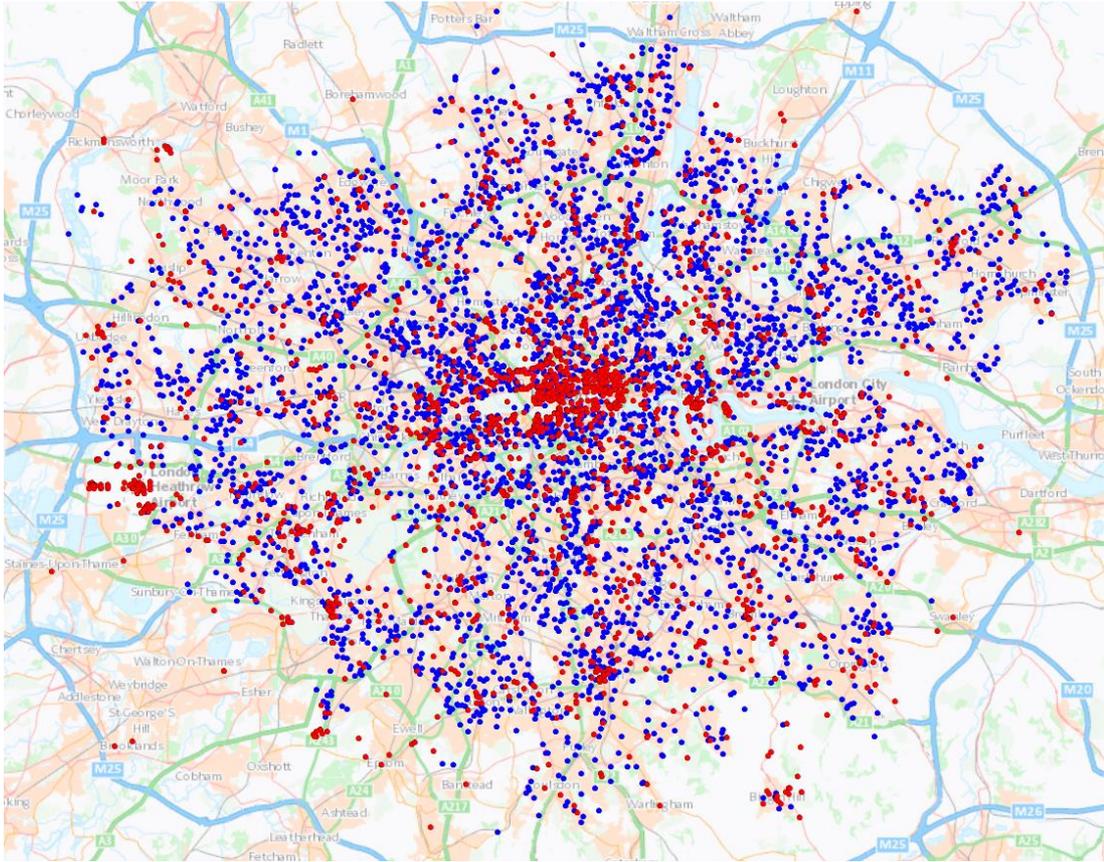
## 7.4 RESULTS

### 7.4.1 Number of OHCA and public-access AEDs

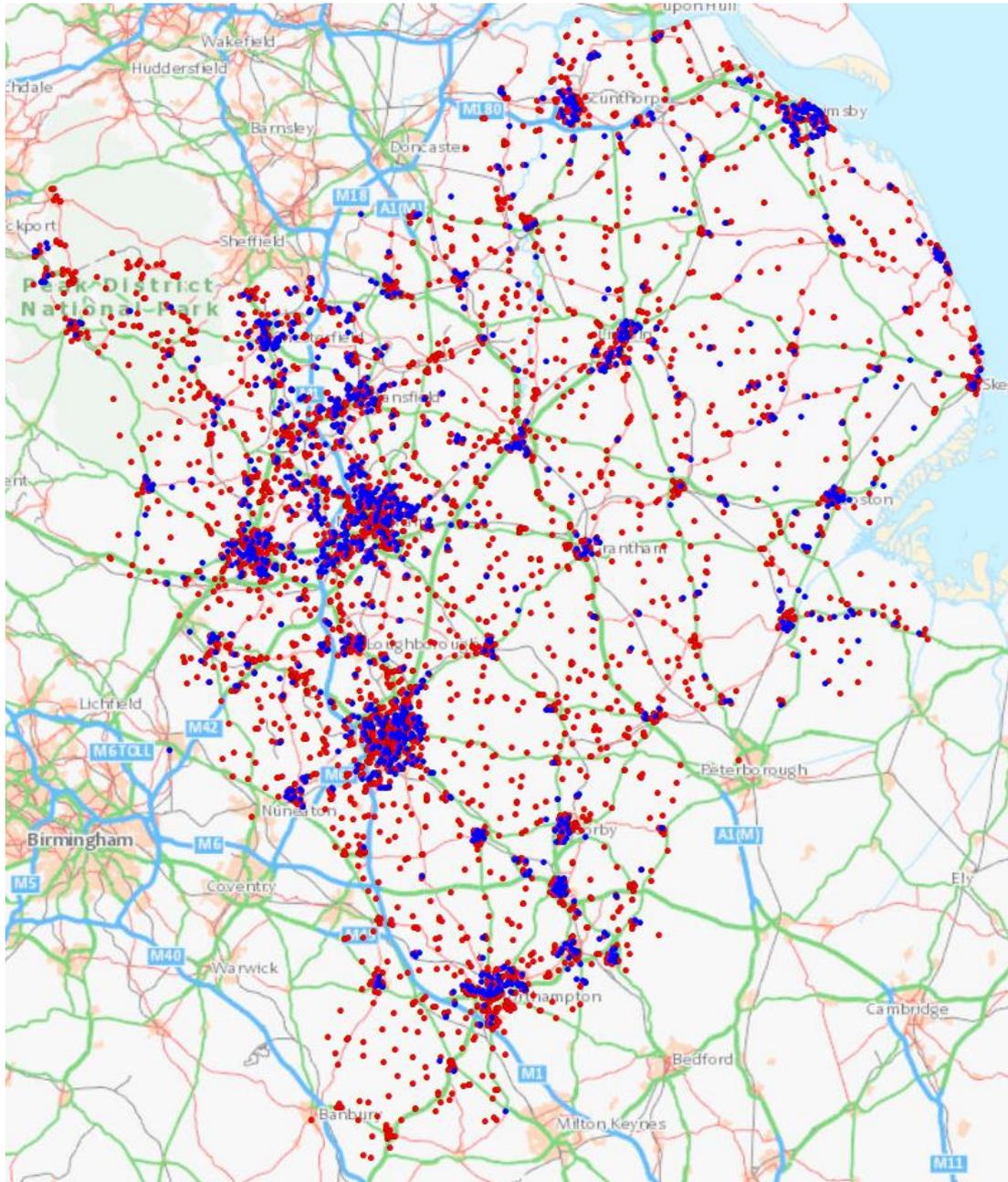
I mapped 4355/4448 (98%) OHCA and 2677 AEDs in London, and 1263/2281 (55%) OHCA and 4704 AEDs in East Midlands during the respective study periods. For the remaining OHCA I did not have precise location data. **Figures 7.3-7.5** display the geographical regions of interest and OHCA and AED locations.



**Figure 7.3: Geographical regions of interest for this chapter**



**Figure 7.4: OHcAs (blue dots) and AEDs (red dots) in London**



**Figure 7.5: OHCA (blue dots) and AEDs (red dots) in East Midlands**

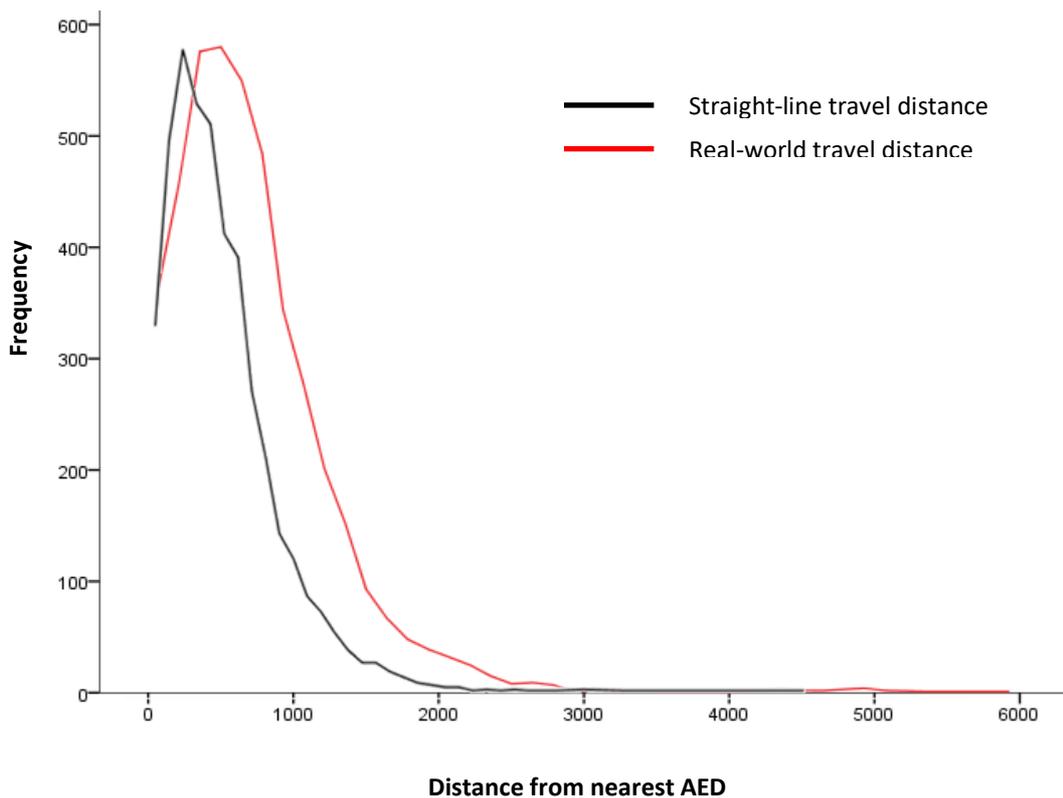
### **7.4.2 Proximity of OHCA to public-access AEDs**

In London an OHCA was a median of 406m (IQR 223-643m) away from the nearest public-access AED by straight-line distance and 623m (IQR 348-953m) away by real-world travel distance ( $p < 0.0001$ ). For a bystander at the scene of an OHCA this would be an extra travel distance of (median) 434m

(217m there and back), equating to an extra (median) 04:20 minutes at a brisk walking speed of 100m/min.

In East Midlands an OHCA was a median of 357m (IQR 201-557m) away from the nearest public-access AED by straight-line distance and 568m (IQR 317-894m) away by real-world travel distance ( $p < 0.0001$ ). For a bystander at the scene of an OHCA this would be an extra travel distance of (median) 422m (211m there and back), equating to an extra (median) 04:13 minutes at a brisk walking speed of 100m/min.

**Figures 7.6 and 7.7** and **Table 7.1** show the distribution of OHCA proximity to the nearest public-access AED

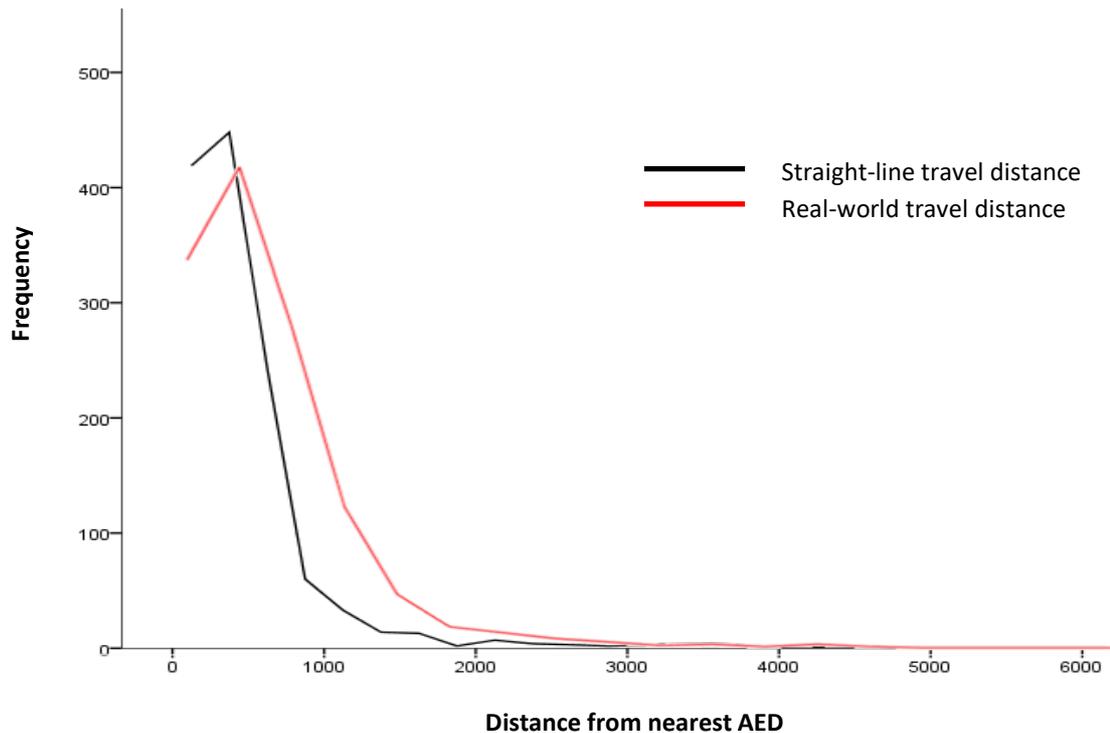


**Figure 7.6: Proximity of OHCA to public-access AEDs in London**

**Table 7.1: Proximity of OHCAs to public-access AEDs**

	London Ambulance Service (n=4355)		East Midlands Ambulance Service (n=1263)	
	Straight-line distance	Real-world travel distance	Straight-line distance	Real-world travel distance
<100m	8.6% (373)	6.3% (273)	8.3% (105)	5.5% (70)
<200m	22% (951)	12% (538)	25% (315)	13% (165)
<300m	36% (1568)	20% (879)	41% (514)	23% (289)
<400m	49% (2136)	30% (1288)	57% (714)	34% (428)
<500m	61% (2650)	39% (1683)	69% (867)	43% (547)
<1000m*	92% (3989)	77% (3358)	93% (1171)	81% (1024)

\*The remaining OHCAs were >1000m from the nearest public-access AED

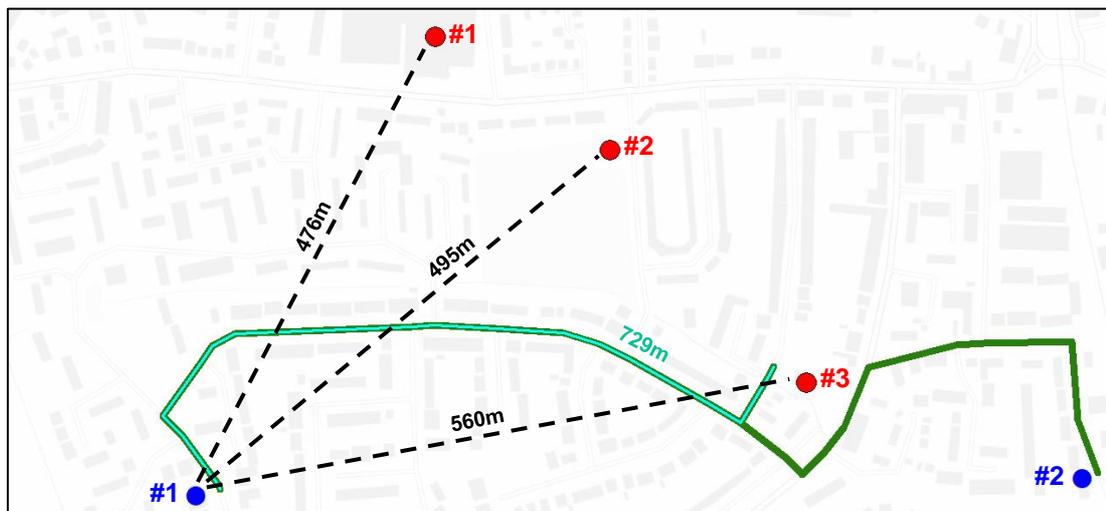


**Figure 7.7: Proximity of OHCAs to public-access AEDs in East Midlands**

In London, there were 1546 sites that had a single AED registered. There were 305 sites with multiple AEDs, requiring manual checking and updating of the Eastings and Northings for 1131 AEDs at these sites. There were three examples in London and one in East Midlands where the location data was clearly outside the geographical area of interest. In all four cases, I was able

to infer from manually checking the location description and viewing it on Google Maps that the error was due to an inadvertent transcription of two of the figures in the Easting/Northing provided from the source data.

When considering real-world travel distance rather than straight line distance, the identity of the nearest public-access AED to an OHCA changed in 26% (1133/4355) cases in London, and in 26% (329/1263) cases in East Midlands. **Figure 7.8** illustrates an example of this.



**Figure 7.8: Real-world travel vs straight-line travel distance example. OHCA = blue dots. AEDs = red dots. OHCA #1 is closest by straight-line distance (dashed line) to AED #1, but closest by real-world travel distance (light-blue solid line) to AED #3.**

## 7.5 DISCUSSION

### 7.5.1 Main findings

Real-world travel distances from historical OHCA to the nearest public-access AED are more than (a median of) 200m longer than straight-line estimates in London and East Midlands. The proportion of OHCA within 100m of the nearest AED fell from 8.6% to 6.3% in London and 8.3% to 5.5% in East Midlands when using real-world travel distance estimates. For bystanders at the scene of an OHCA in London or East Midlands asked to retrieve a public-access AED, using real-world travel routes would have taken more than four

minutes longer at a brisk walking pace. The identity of the nearest public-access AED changed in 26% in both regions when using real-world travel distance estimates.

### **7.5.2 Comparison with the literature**

The proportion of OHCA within 100m (6.3% London and 5.5% East Midlands) and 500m (39% London and 43% East Midlands) of the nearest public-access AED are similar to those reported in the South Central Ambulance Service region (5.9% <100m and 36% <500m), whose authors also calculated real-world travel distances using a GIS programme (276).

Researchers in Hong Kong (277) also demonstrated substantially increased travel distances between historical OHCA and public-access AEDs using real-world estimates via roads and paths rather than straight-line estimates. In that study, the average distance increased from 231m to 543m for 5119 historical OHCA to the nearest of 1637 AEDs). The discrepancy between AED coverage at 100m using straight line (30%) vs real-world travel distance (11%) was greater than in the current study in either London or East Midlands. They did not report whether or not the identity of the nearest public-access AED changed in any of the OHCA.

However, many other studies to date have reported AED coverage using straight-line distance estimates. In urban areas, 3-25% of historical OHCA are within 100m of a public-access AED by a straight-line estimate (111).

### **7.5.3 Strengths and limitations**

This is the first study to specifically report that the identity of the nearest available public-access AED for an OHCA patient changes in a substantial number of cases when calculating real-world rather than straight-line travel distance. I used ArcGIS, a paid-for GIS programme available through my University, but there is freely available GIS software. The Ordnance Survey maps that I used to calculate real-world travel distance are open-source.

I was not able to accurately plot locations for many OHCA in East Midlands, and so the results from this area are limited to 55% of the total OHCA during the study period. I am unable to estimate the geographical distribution of OHCA that I excluded and how this would have affected the median distance (and IQR) to the nearest public-access AED. However, it is very unlikely to change the important finding that there is a significant (>200m) increase in the median value when calculating real-world travel distance.

There were issues with AED location accuracy. In many cases, AEDs are mapped to single buildings and locating their exact position inside is not possible. Thus the distance estimates may be inaccurate by a number of metres – tens of metres in larger buildings. I have already described the manual checking of larger sites with multiple AEDs sharing the same six-figure Easting/Northing value from the London dataset. I used a number of complementary techniques to overcome this but it is possible that the estimate for the corrected Easting/Northing was slightly inaccurate in some cases.

For both datasets I was relying on the accuracy of the AED location data provided, although I was able to manually check a random selection of Easting/Northings against location description in each dataset. There were three cases in London and one in East Midlands where the location data was clearly incorrect, because the point plotted in ArcGIS was outside the geographical area of interest. Such errors were obvious, but it raises the possibility of other errors that are not obvious and that I may not have found.

LAS provided installation dates for their AEDs but EMAS did not: it may be for the latter dataset that some AEDs were not present at their current location at the time of the historical OHCA. In addition, I did not consider availability and accessibility of public-access AEDs in this chapter, which is often reduced out-of-hours ((111) and see work in **chapter 4**). Thus, findings in this chapter represent an estimate of the potential for public-access AED use in ideal circumstances: in reality the nearest AED will not always be the nearest one available for use for that particular OHCA.

There are some limits because of the maps that I used and the Network Analyst Tool that calculates travel distance via roads and paths. The Network Analyst calculated start and stop locations for its route at points on a road nearest to where the AED was located. This does not take account of the distance from the roadside to the AED – for example, across a carpark or pedestrianised area to a building where an AED is installed. This may underestimate the distance travelled to retrieve a public-access AED on some occasions. On other occasions the stop location on the Network Analyst calculation may be the closest point to a building holding an AED, but the nature of the access to the building (e.g. on the far side of the building) may mean that the stop location is *not* the most convenient one.

There are also occasions where most of the travelling required to reach a public-access AED, is *not* on recognised roads and paths that appear on maps. On these occasions, the real-world travel distance (taking account of mappable roads and paths only) is erroneously reported as being *shorter* than the straight-line distance. This happened in 6.8% (298/4355) of cases in London and 7.0% (89/1263) of cases in East Midlands. Clearly, this is not physically possible – the shortest distance between two points is a straight line, by definition – and so the difference in median travel distance between straight-line and real-world estimates will be even larger than reported here.

The travel network I set up in ArcGIS was based on the assumption that the rescuer would travel on foot to retrieve a nearby AED, but this may not always be the case ([173](#)). If travelling by motorised vehicle a travel network in ArcGIS or similar software would have to take account of restrictions such as one-way streets and junctions where turns in certain directions are not permitted (for example ‘No Right Turns’). I used free, open-source Vector Maps (OS Open Local) to overlay the network of roads and paths onto my basemap, and the accuracy of travel distance depends on how many of the available roads and paths are displayed on it. OS Mastermap is considered the definitive map of geographical features in Great Britain and there are ongoing efforts to make this map freely available. It may provide more detail about smaller navigable paths and roads, and has an ‘Integrated Transport Network’ Layer of all

highways which includes information on restricted road access and turn restrictions (see <https://www.ordnancesurvey.co.uk/business-government/products>).

I measured 'Planar' distances between OHCA and AEDs as the Ordnance Survey basemap uses a Projected Coordinate System and is essentially a two-dimensional map. It is also possible to measure 'Geodesic' distances, which take into account the curvature of the earth and can produce marked differences from the 'Planar' method of distance estimation over long distances (313). However, I compared straight-line distance estimates on my datasets using Planar and Geodesic techniques. The difference in distance estimates was less than one metre for a 5km straight line distance (data not shown).

#### **7.5.4 Clinical implications**

In both London and East Midlands the increased median time required for a bystander at an OHCA to retrieve a public-access AED would be more than four minutes if calculating real-world rather than straight-line travel distance. A four-minute delay to defibrillation, when the patient is in a shockable rhythm, is likely to be clinically relevant and affect patient outcomes.

Although it was not formally assessed, the visual data suggest more of a clustering effect for OHCA than for AEDs. Indiscriminate placement of AEDs may not be clinically appropriate (126,151) or cost-effective (152-154), but models that optimise AED placement based on OHCA location and incidence (178,179) should take account of the increase in retrieval distance and time estimates using real-world travel routes that I have demonstrated here.

UK ambulance services have different 'operational AED retrieval' distances (276). The greater that distance the more likely the ambulance service will deem an AED retrievable, but the less likely that it will be brought to scene before the ambulance service arrives or in time to make a meaningful difference to survival. In any circumstance, using straight-line travel distance

(and time) estimates will lead to an overestimation of the number of times a bystander can successfully attach a public-access AED to a patient. Crucially, it will likely result in circumstances when a bystander is dispatched to a particular public-access AED when another one is closer and could be retrieved sooner.

There is a clear argument for ambulance services to use systems that estimate travel time and distance using real-world travel routes. This is particularly relevant now that a new national database – ‘The Circuit’ (109) – has been launched across the UK. The list of public-access AEDs that ambulance services are aware of is more comprehensive than it ever has been, and this provides an opportunity to more accurately map AED locations and report on their availability both in- and out-of-hours. Ambulance services can improve public-access AED use by directing bystanders to the most appropriate one and accurately estimating whether this can be done in a meaningful timeframe.

There are other barriers to successful public-access AED retrieval. Once a bystander has travelled to the AED site, they have to locate the device and may have to negotiate with a local AED custodian for its release. More accurate recording of AED locations may help, but many AEDs are not accessible out-of-hours (179,181,276,315) and ambulance services should account for this reduced availability when directing bystanders. Indeed, in this study, both ambulance services provided a list of public-access AEDs that included those in locations that might not be accessible 24/7.

Modelling travel time and distance using real-world routes is not without problems. Out-of-date maps, or maps that do not show all roads and paths may result in longer travel distances than necessary. Routes may not always be accessible to walkers because of difficult terrain, and crossing major roads may be difficult or even dangerous if there are not recognised crossing points (316). OHCA and AED locations as latitude and longitude or Eastings and Northings do not take account of height differences. An AED kept on the third floor of an office block will take much longer to locate and retrieve than one in

the ground floor lobby, but might have exactly the same two-dimensional map coordinates.

A study from Sweden recorded an average walking speed of 138m/min (faster than estimated in this chapter) for volunteer first-responders travelling to an OHCA patient (317). Bystanders may also travel using their own vehicle (173). Both reduce estimates of time to AED retrieval. If modelling AED retrieval using motor vehicle, the network analysis should model permissible routes – accounting for one-way streets, no turns allowed, and restricted access to certain vehicle types – and adjust travel time estimates accordingly.

Many of these concerns are also relevant to app-based volunteer first-responder systems such as GoodSAM. If volunteer first-responders are asked to retrieve an AED on their way to the patient this adds significantly to travel distance and time (173). An accurate location for the public-access AED, with route information and descriptive information about the location (e.g. “AED is on the outside wall next to the ATM, code for the cabinet is 1234”) sent to the responder’s mobile device, would aid timely retrieval.

The distance to the nearest public-access AED is likely related to whether or not it is used (280,282) but there is no evidence that the proximity of a public-access AED directly correlates to improved clinical outcomes. In **chapter 6**, (straight-line) distance to the nearest AED was not a predictor of OHCA survival in London (2016–2017) in a multiple logistic regression model. It is entirely plausible that AED proximity should influence outcomes, particularly in witnessed and promptly-recognised OHCA where defibrillation can potentially occur soon after collapse, but only if we can overcome other barriers to successful public-access AED use.

### **7.5.5 Next steps**

There are several barriers to successful public-access AED use, and many of these concern timely location and retrieval of the AED. Strategic AED placement based on predicted OHCA location can be optimised further by

accounting for both real-world travel distances (318) and reduced availability out-of-hours (179,181,276,315).

I will present and publish work from this chapter. I intend to share the findings with local ambulance services and British Heart Foundation representatives involved with The Circuit database so that they can consider the need for better modelling of travel time and distance between OHCA and the nearest available public-access AED.

## **7.6 CONCLUSION**

Real-world travel distances were significantly longer than straight-line estimates for public-access AED retrieval in historical OHCA in London and East Midlands. Using real-world travel routes reduced estimates of AED coverage and increased estimates of travel time for bystanders who might retrieve a public-access AED. The identity of the nearest public-access AED changed in over a quarter of cases in both London and East Midlands. This has substantial implications for ambulance services that instruct bystanders at the scene of an OHCA to retrieve an AED and/or dispatch AED custodians to the scene. Ambulance services should use systems that allow them to identify the nearest accessible public-access AED using real-world travel distances. These systems should ideally account for route obstacles and reduced availability of public-access AEDs out-of-hours.

# CHAPTER 8

## Barriers and facilitators to Automated External Defibrillator use by volunteers in the GoodSAM first- responder system

---

Part of this chapter has already been published ([189](#)):

**Smith CM**, Griffiths F, Fothergill RT et al. Identifying and overcoming barriers to automated external defibrillator use by GoodSAM volunteer first responders in out-of-hospital cardiac arrest using the Theoretical Domains Framework and Behaviour Change Wheel: a qualitative study. *BMJ Open* 2020;10:e034908

---

## **8.1 INTRODUCTION**

### **8.1.1 Out-of-hospital cardiac arrest**

In London ([319](#)), and across England ([12](#)) around one in ten patients who sustain an out-of-hospital cardiac arrest (OHCA) survive to hospital discharge. Earlier defibrillation of a fibrillating heart and good-quality chest compressions during cardiopulmonary resuscitation (CPR) at least double the chances of survival ([6,69](#)). Bystanders can perform defibrillation before the ambulance service arrives using a public-access Automated External Defibrillator (AED) – a strategy known as Public Access Defibrillation (PAD). This occurred in only 4.5% of OHCA in England in 2018 ([12](#)).

Barriers to PAD include limited knowledge and awareness of AEDs and their location, variable willingness to locate and use public-access AEDs, and difficulties in accessing them ([111](#)). To improve survival we need effective strategies to improve bystander public-access AED use and the community response to OHCA in general.

### **8.1.2 The GoodSAM first-responder app**

A number of mobile-phone app-based systems have been developed to alert volunteer first-responders to a nearby OHCA. GoodSAM is the system used by London Ambulance Service (LAS) and in several other ambulance services across the UK.

During a 999 call in London, a call handler at the Emergency Operations Centre (EOC), with the help of the Medical Dispatch Priority System (MPDS), identifies and allocates a code that best categorises the problem that is being reported. LAS identified eight MPDS codes that historically had best indicated a patient sustaining a current or imminent OHCA (see **chapter 5, Table 5.1**).

If one of these codes is allocated, an audible alert siren is automatically played via the app to any GoodSAM responder within a certain distance of the patient. At the time of this study, this was an alerting radius of 300m in London. Global Positioning System (GPS) is used to map the position of the responders' phone in real-time. They then have the option to accept or reject the alert. If they accept an alert they are given the incident address and, if required, a route to the address.

GoodSAM and LAS also share a database of public-access AEDs, whose locations are displayed on the app. GoodSAM responders decide whether to retrieve an AED or travel directly to scene, but receive no specific instruction about this via the app.

GoodSAM responders are classified into different categories:

- Tier 1: Doctors, nurses, paramedics – governed nationally
- Tier 2: Community first-responders, Emergency Medical Technicians – governed regionally
- Tier 3: Individuals with current training in CPR/AED – no formal governance

To register with GoodSAM in the UK people must have at least an in-date CPR certificate. Users upload the certificate via the app and GoodSAM verify it. Tier 1 and 2 responders are verified either via their professional registration number (by GoodSAM) or by their employer (many of whom are affiliated with GoodSAM, e.g. LAS). There is no assessment of CPR training quality, and no ongoing appraisal of responders' cardiac arrest management skills.

## **8.2 AIM AND OBJECTIVES**

The aim in this chapter was to identify barriers and facilitators to AED use by GoodSAM responders when responding to an alert in London.

I will identify potential barriers and facilitators in interviews with GoodSAM responders and with Key Informants from LAS and GoodSAM, classify these barriers and facilitators using the Theoretical Domains Framework (TDF) and map domains of the TDF to the COM-B (Capability, Opportunity, Motivation) Behavioural Framework.

## **8.3 METHODS**

### **8.3.1 Methodological approach: use of a theoretical framework**

The work in this chapter represents the first use of validated behavioural frameworks to investigate barriers and facilitators to AED use in a volunteer first-responder system.

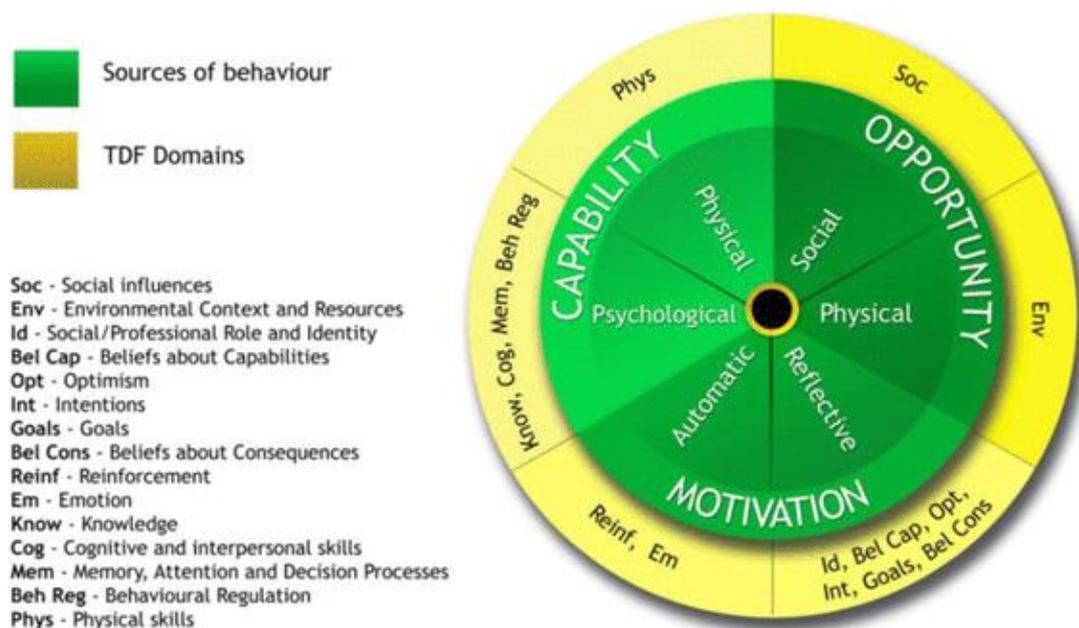
The TDF is a ‘determinant’ framework (320), used to identify groups of similar factors that are barriers or facilitators to a particular outcome (185,321). It is validated to assess behaviours relevant to implementation of specific interventions (196), and is used for individuals, groups or populations (321).

The original TDF was developed by expert consensus. ‘Theoretical constructs’ relating to behavioural change were grouped into 12 categories or ‘domains’ (321). The revised version, developed following external validation, now contains 14 domains (196):

- Knowledge
- Skills
- Social/Professional Role and Identity
- Beliefs about Capabilities

- Optimism
- Beliefs about Consequences
- Reinforcement
- Intentions
- Goals
- Memory, Attention and Decision Processes
- Environmental Context and Resources
- Social Influences
- Emotion
- Behavioural Regulation

TDF domains can be further grouped, and so integrated with the COM-B (Capability, Opportunity, Motivation) behavioural framework (**Figure 8.1**). The COM-B model characterises three core targets for behavioural change in order to inform the design of healthcare interventions (198). This is particularly useful as COM-B can, in turn, be linked to the Behaviour Change Wheel (BCW) (199). The BCW can then be used to develop interventions and effective means of implementing behavioural change.



**Figure 8.1: The COM-B model, and how domains of the TDF integrate with it. From Atkins et al. 2017 (185), p11 of 18**

### **8.3.2 Participants**

GoodSAM sent e-mails (on my behalf) to GoodSAM responders informing them of the study shortly after they had received a GoodSAM alert. All responders were eligible to participate, regardless of whether or not they had accepted an alert. GoodSAM sent e-mails in batches, with two e-mail rounds in July 2018, and three more in October 2018:

- Thursday 19<sup>th</sup> July (to those receiving alerts in the previous seven days)
- Tuesday 24<sup>th</sup> July (covering period since previous e-mail)
- Wednesday 24<sup>th</sup> October (to those receiving alerts in the previous 48 hours)
- Friday 26<sup>th</sup> October (covering period since previous e-mail)
- Monday 29<sup>th</sup> October (covering period since previous e-mail)

I identified two Key Informants involved in the integration of GoodSAM with LAS from existing contacts from both organisations on this project's steering committee. I approached them myself via e-mail and invited them to participate.

Additionally, as part of this PhD I undertook a training visit to a research team in Copenhagen, Denmark, who co-ordinate the 'Hearrunner' volunteer first-responder system, to understand some issues that may be common to these systems. I have incorporated the relevant learning from this visit in this chapter.

### **8.3.3 Interview process**

I conducted interviews with GoodSAM responders by telephone, lasting a median of 14:56 minutes (range 7:41-24:01). I conducted two face-to-face Key Informant interviews, lasting 37:13 and 24:30 minutes.

I drafted Participant Information Sheets and consent statements using University templates, following Warwick Clinical Trials Unit (CTU) guidelines: <https://www2.warwick.ac.uk/fac/med/research/ctu/conducting/during/consent>. These documents are available in the **Appendix (chapter 14)**.

The e-mail inviting GoodSAM responders to participate included the Participant Information Sheet and consent statements as attachments. Those who wished to participate replied to me and provided a valid contact telephone number to arrange a time for interview, scheduled for at least 24 hours after their reply. I sent no follow-up e-mails to non-respondents. At the start of the telephone call I informed participants at the moment that I began recording (immediately after introductions and confirming participant identity) and that the recording would continue until the end of the telephone call. I obtained verbal agreements to each of the consent statements in turn: this was part of the audio recording for each interview, so there exists a lasting record of the consent process. I then began the interview questions.

Each participant was interviewed on one occasion. Interviews were 'semi-structured' in that they started with open-ended questions and I used a brief topic guide with prompting questions to explore further the important issues that arose ([322](#)). This was appropriate given the specific topic area (AED use during a GoodSAM) in a well-defined and reasonably homogeneous interview population (GoodSAM responders who had recently received an alert, or the limited number of Key Informants).

I conducted telephone interviews from a private room at the University of Warwick using Microsoft Skype (audio only) to the telephone number the participant provided. This allowed direct recording of the interview onto a computer (using QuickTime Player). A back-up recording was made using an encrypted audio device. I saved audio files into an encrypted folder at the University of Warwick. Once I had checked that the audio files had been transferred successfully, I deleted the recordings from the encrypted audio device.

I chose individual interviews to focus on the individual and their own personal viewpoint of their experience and/or actions (323), and to allow for the privacy that may be required to get honest and complete answers (192). It may be harder to gain an initial rapport during remote interviews (324), particularly if the interviewer and participant cannot see each other and respond to non-verbal cues (325). Responding to such cues might potentially have prompted more in-depth discussions. However, telephone interviews allowed me to interview geographically remote participants (326) – at a time of their choosing – within seven days of the most recent GoodSAM alert, and eliminated personal security concerns (327). None of this would have been feasible with face-to-face interviews, given the number of interviews that I wanted to conduct in the short (seven-day) time-frame required to facilitate accurate recall and honest reflection on performance (328,329). Video calls were considered, but I was concerned about excluding respondents based on whether or not they had access to reliable video-call technology.

I also considered using focus groups to gather the requisite information from GoodSAM responders. It would have proved difficult to organise a time and location to bring together a group of GoodSAM responders who were all within seven days of their most recent alert. Additionally, focus groups would have been a better means of reaching consensus about the correct actions during a GoodSAM alert, rather than recording individual experiences during a sensitive and time-critical situation. I could have not assured anonymity to each participant, as this relies on the discretion of all group members. Some participants might therefore be reluctant to speak in a group setting about decision-making that might impact on patient outcome (330). This was better controlled during telephone interviews and the offer of support for participants was part of the Participant Information Sheet and interview schedule information for this study.

The term ‘something’ rather than ‘anything’ was used in questions at the end of interviews (e.g. ‘is there something that could make it easier to get a defibrillator?’). In a study from Pennsylvania, USA, 20 doctors in two outpatient clinics were randomly allocated to ask 224 patients, “Is there anything else you

want to address in the visit today?” or, “Is there something else you want to address in the visit today?”. Patients asked “something” were more likely to answer yes (90.3% “something” vs 53.1% “anything”,  $p=0.003$ ). The “something” question identified previously unmet concerns in 78% of patients, compared to in 37% of patients asked the “anything” question (331).

I set an initial sample size of 30 for GoodSAM responder interviews. This is consistent with a sample of PhD studies using qualitative methodologies that reported a mean sample size of 31 and a mode of 30 (332). It was also a pragmatic and achievable number of interviews. This was a group with some degree of homogeneity and a certain level of expertise, concentrating on a specific area (the use of an AED) in a specific situation (volunteer first-response to an OHCA); these factors should diminish the sample size required (333).

I first tested for data saturation – defined in this study as no more new information emerging from three consecutive interviews (334) – after interviews 28, 29 and 30.

The e-mail to Key Informants similarly contained a Participant Information Sheet and Consent Form as an attachment. They arranged a time and location for interview with me e-mail. An identical written version of the consent form was brought to the interview. Consent was re-confirmed and both participant and interviewer signed the form. I recorded interviews onto an encrypted audio device provided by the University of Warwick. The file was transferred to an encrypted folder on a computer at the University of Warwick within 24 hours, and the original recording deleted.

The Key Informant interview sample size was limited by the number of relevant people that knew about the integration of GoodSAM into LAS systems.

I developed an interview schedule and topic guide for both the GoodSAM responder and Key Informant interviews. These are available in the **appendix (chapter 14)**. The two PPI members of the project’s steering group reviewed

these documents for their suitability. The emphasis was on the decision to retrieve and use an AED and the decision to accept or reject the GoodSAM alert. The questions focussed on aspects of capability, opportunity and motivation relating to these actions.

#### **8.3.4 Transcription, coding and analysis**

I transcribed the 30 GoodSAM responder interviews and the two Key Information interviews into a Microsoft Word (Microsoft Corporation, Washington, USA) document and imported these into NVivo (version 12, QSR International, Melbourne, Australia). I subsequently stored both documents in an encrypted folder at the University of Warwick.

I undertook a descriptive, line-by-line coding of the first three GoodSAM responder interviews that I had transcribed. FG (PhD supervisor) reviewed this coding and we made a judgment from the codes and themes emerging that these matched sufficiently with the domains of the TDF for us to continue coding to these domains for all interviews. I subsequently coded all of the interview responses to TDF domains as soon after the interview had taken place as practical. This was an iterative process – FG checked my coding using the TDF on three transcripts – and I then reviewed all of the coded interviews a second time as my understanding and familiarity of the TDF increased. I remained alert to any data relevant to the research question that could not appropriately be coded to a TDF domain.

I created a matrix of all coded material from interviews in each TDF domain, and matched these domains to 'Capability', 'Opportunity' or 'Motivation'. I added my own analysis at this stage to clarify how this coded information would be a barrier or facilitator to AED use during a GoodSAM alert. In so ordering the TDF domains, and in my subsequent analytical inferences, I began to synthesise a narrative about the experiences of the GoodSAM responder. This was true both for the moments after a responder received an alert and for any preparation that they might make for an alert. I analysed how this had or might influence whether or not they used (or would use) an AED.

Ultimately, I decided that presenting the findings according to whether they reflected capability, opportunity or motivation to undertake a relevant behaviour was a better means of communicating findings than by TDF domain.

### **8.3.5 Ethical considerations**

The study (presented across both **chapter 8 and 9**) received ethical approval from the Biomedical Sciences Research Ethics Committee (BSREC) at the University of Warwick on 16<sup>th</sup> March 2018 (REGO-2018-2164).

GoodSAM responders act in a ‘Good Samaritan’ role when responding to a GoodSAM alert. Participants were therefore considered bystanders and *not* recruited by virtue of their professional role. All interview participants were adults, and capacity was presumed. This study placed no additional responsibilities or liabilities on participants. I spoke to GoodSAM responders about potentially sensitive issues shortly after they had received an alert. The written interview schedule, which I kept available during interviews, included contact numbers for support agencies and advice on what I should do if there was an immediate concern of harm. This was based on a ‘Sensitive Interview Action’ card developed by Warwick CTU – available in the **Appendix (chapter 14)**.

I did not provide clinical advice. The plan was to direct participants to resuscitation guidelines published by Resuscitation Council UK (<https://www.resus.org.uk>) for this, or to GoodSAM itself for technical questions or concerns about liability or governance.

No participant-identifying information was associated or stored with audio files or transcripts of interviews, nor reported in any project outputs.

## **8.4 RESULTS**

I conducted 30 telephone interviews with GoodSAM responders. Twenty-one interviews took place in July 2018 after two rounds of invitation e-mails. I

transcribed these interviews and reviewed them with FG (PhD supervisor) to ensure that the topic guide was suitable. I had initially recruited a higher proportion of people who had accepted a GoodSAM alert than the London average – 57% (12/21), compared to 19% in London that month (information from GoodSAM). I therefore only sent out e-mail invitations for the last nine interviews to people who had rejected their latest GoodSAM alert. I conducted the remaining nine interviews in October 2018. No participant mentioned adverse events or psychological concerns requiring intervention during the interview process.

In total, there were 248 e-mail invitations sent out, and 40 people agreed to participate. Three people did not subsequently provide contact details or communicate further, six replied once the threshold of 30 interviews had been reached, and one was a GoodSAM responder in a different area of the country who had mistakenly been sent an invitation e-mail.

There were eleven Tier 1 participants (37%), nine Tier 2 participants (30%) and ten Tier 3 participants (33%). For comparison, the overall worldwide pool of GoodSAM responders at the time was: 43% Tier 1, 13% Tier 2 and 44% Tier 3. GoodSAM did not have a record of UK-specific figures.

After 30 interviews, my supervisor (FG) and I agreed that we had met the threshold for data saturation. I coded all relevant information to a TDF domain.

Overall, when considering only the most recent alert, 47% (14/30) accepted the alert. Of these fourteen people, six reached the patient's side; three of these six arrived before the ambulance and were first on-scene. Four of eleven patients, where this was known, had actually sustained an OHCA. Most participants had received multiple GoodSAM alerts. In the majority of cases, participants had experience of both accepting and rejecting alerts.

I interviewed two Key Informants in May 2018. Both were LAS staff involved in the integration between GoodSAM and LAS Computer-Aided Dispatch systems.

**Table 8.1** summarises barriers and facilitators to AED use by GoodSAM responders that I identified during interviews

**Table 8.1: Barriers and facilitators to AED use by GoodSAM responders**

<b>CAPABILITY</b>
<i>Facilitators</i>
<p>Previous training in CPR/AED use</p> <p>Previous real-life experience in CPR/AED use</p> <p>Good awareness of Public Access Defibrillation</p> <p>Using the app to check AED locations before an alert</p> <p>Feeling capable and competent to respond to alerts</p>
<i>Barriers</i>
<p>Being less familiar of AED locations in unfamiliar areas</p> <p>Varying recall of information given during an actual alert</p> <p>Not recalling if AED locations were displayed at time of the alert</p> <p>Not even considering AED retrieval at the time of the alert</p>
<b>OPPORTUNITY</b>
<i>Facilitators</i>
<p>Having one's own AED (Some GoodSAM responders did and had taken them to scene)</p> <p>Previously known AED available nearby</p> <p>AED already present on scene</p>
<i>Barriers</i>
<p>Public-access AEDs</p> <ul style="list-style-type: none"> <li>Perceived to be too far away from GoodSAM responder or patient at time of alert</li> <li>Perceived difficulty finding exact location</li> <li>Less availability during out-of-hours alerts</li> <li>Perceived to be inaccessible in locked cabinets</li> </ul> <p>App-specific issues:</p> <ul style="list-style-type: none"> <li>GoodSAM location inaccurate at time of alert</li> <li>Alert siren not always heard</li> <li>App slow to display incident location once alert accepted</li> </ul> <p>Healthcare professionals unable to leave patients at work to respond</p> <p>Non-healthcare professionals feeling unable to leave work or dependents</p> <p>Arriving after the ambulance service</p>

## MOTIVATION

### *Facilitators*

A desire to help  
Confidence in CPR and AED use: backed up by previous training and experience  
Debrief and follow-up after an alert  
Belief in the GoodSAM project and its benefit to patients  
Knowledge that other GoodSAM responders were responding  
Belief in the importance of CPR and AED use to patient survival  
Belief that delivering a shock as soon as possible is important  
Planning ahead by finding AED locations  
Anxiety about their ability to respond rarely reported  
Promoting the GoodSAM app at CPR training events

### *Barriers*

Concerns about managing scene  
User-app interaction

- Confusion about seemingly redundant functions
- Lack of clarity about if/how you can communicate with other responders

A lack of immediate social pressure to respond to a remote incident  
Concerns about managing non-OHCAs

- Concerns re: duty of care
- Less confidence in abilities in this circumstance

Belief that ambulance service response time would be short  
Reduced motivation because of experience during recent alert(s):

- Too far from incident
- Belief that ambulance service would arrive before them
- Arriving after the ambulance service, even if accepting alert promptly
- Not finding a patient in cardiac arrest

Prioritising arrival of scene and starting CPR as soon as possible over AED use  
Not knowing if someone else was responding or providing CPR at scene  
Uncertainty about correct strategy: retrieve AED first or go direct to patient?  
Beliefs about inaccessibility of AEDs in certain circumstances  
Perceived difficulties in negotiation for AED release from its owner / custodian  
Concerns about acting outside normal sphere of work (healthcare professionals)

### 8.4.1 **Capability**

#### *Physical Capability*

Every participant who commented on previous CPR/AED training believed this facilitated effective CPR and AED use during a GoodSAM alert. No participant said that they felt unable to provide CPR or use an AED if required.

Twenty participants reported real-life experience of OHcAs; sixteen had done this during a GoodSAM alert. Eight participants reported that this would help them to provide effective CPR and defibrillation in future GoodSAM alerts.

#### *Psychological Capability*

Participants were knowledgeable about public-access AEDs, their likely locations and that they were visually represented on the GoodSAM app:

“I’m aware that tube stations, Pret [sandwich shop chain], the usual kind of suspects will have them, so there’s quite a few within close proximity, not on my route, but if I needed help I could direct someone, go to just up the street, go to Boots” (#10, Tier 2)

Participants often checked AED locations on the GoodSAM app at other times. Twelve participants reported knowledge of AED locations in their home area, and four commented that they were less knowledgeable about AED locations in other areas:

“Most places I wouldn’t [know where an AED was] unless I looked on the GoodSAM app and it was on the map.” (#20, Tier 1)

Three participants reported knowing of AEDs on the app that were unavailable out-of-hours (#12, Tier 3; #14, Tier 1, #24 Tier 3). Six participants only knew about an AED’s location after seeing it on the app.

Nine participants reported not remembering which information, including AED location, was displayed on their phone screen at the moment of the alert. Seven others did remember that an AED's position was displayed at the time of the alert.

Two participants (#8, Tier 3; #28, Tier 1) had mistaken the alert siren for another alarm in the local area, and so did not react to it. One participant (#2, Tier 3) had tested the siren noise before receiving an alert.

Two participants (#23, Tier 1; #8, Tier 3) said that they had not considered finding an AED after a GoodSAM alert. One commented:

“This is the first time I've thought about the defib, since you mentioned it.” (#8, Tier 3)

One participant, who had rejected all previous alerts, said that the fact that a patient wasn't immediately in front of them meant they felt less able to overcome their lack of confidence in their own capability:

“It's easier to be influenced I think by a lack of confidence if it's not a real human being in front of you, visibly having a problem.” (#21, Tier 3)

#### **8.4.2 Opportunity**

##### *Social Opportunity*

Nearly all participants had responded to at least one alert. One participant, who had rejected all previous alerts, mentioned a lack of immediate social or peer pressure to act, as the situation occurs remotely:

“I think when you're confronted with the abstract notion of doing it, it's quite easy to sidestep it... I think if that person was right in front of you, you would just do it, but I think when it's a piece of technology

telling you if you run fifteen minutes in that direction, um, there's a possibility you might be useful. I think it's a separate move." (#21, Tier 3)

Five participants stated that they would not respond if impaired by alcohol. One participant (#30, Tier 2) implied that alcohol intake might not *absolutely* preclude a response:

"So it would be my judgement call of say I was out with friends and I'd had a few drinks I probably wouldn't go down." (#30, Tier 2)

No participant made direct mention of GoodSAM's Code of Conduct ([298](#)), which specifies that the GoodSAM responder must be alert and not have consumed alcohol.

### *Physical Opportunity*

GoodSAM alerts trigger automatically if there is a responder close enough to the patient. This process is not visible to the 999 call-handler. The aim is to prevent changes to existing ambulance dispatch procedures based on such knowledge, particularly at times of high demand and competing priorities (Key Informants).

Four participants (#2, Tier 3; #9, Tier 3; #16, Tier 2; #17, Tier 2) indicated that existing knowledge of an incident's location facilitated their arrival on scene. Although the GoodSAM Code of Conduct instructs responders only to respond by foot, three participants (#6; Tier 2; #13, Tier 2; #22, Tier 1) travelled to the scene by private vehicle. One participant (#8, Tier 3) drove there in their (empty) taxicab whilst on duty.

Five healthcare professionals reported being unable to respond to an alert because they were already at work caring for other patients. Three others (#9, Tier 3; #15, Tier 3; #18, Tier 3) did not respond because of personal

dependents, and two in non-healthcare roles (#8, Tier 3; #19, Tier 3) felt unable to leave their current work situation:

“I was delivering [first-aid] training and there was a call, it was around the corner from me for respiratory arrest and I was quickly weighing up do I take a class of twelve learners with me for the experience. I would have a responsibility to them as well as towards the patient, and I rejected because I couldn’t just leave the class and I couldn’t take them with me.” (#19, Tier 3).

One participant (#3, Tier 2) felt able to leave immediately from their work environment.

Three participants (#19, Tier 3; #21, Tier 3; #27, Tier 1) reported not responding to an alert because they were away from their phone at the time, and four (#6, Tier 2; #21, Tier 3; #23, Tier 1; #27, Tier 1) reported being unable to alight from public transport.

Some app-specific issues affected participants’ ability to respond to an alert. Three reported that it was slow to load (#16, Tier 2; #19, Tier 3; #25, Tier 1), or could take “three or four minutes” to get address information on the app (#25, Tier 1). Two participants (#7, Tier 2; #25, Tier 1) reported that alerts were cancelled soon after accepting them, and the reasons for this were not clear to them. Seven participants reported not having heard the alert siren, even after an April 2018 update that allows it to sound even in ‘silent’ mode. Participant #23 (Tier 1) mentioned missing GoodSAM alerts because the siren did not sound with the media volume muted, even though the phone was not in silent mode for calls.

Seven participants reported that GoodSAM incorrectly recorded their location at the time of an alert. “1440 metres” was reported by participant #17 (Tier 2) and “four kilometres” by participant #2 (Tier 3). Participant #3 (Tier 2) realised that this might be related to the GPS location accuracy setting on the app itself

and subsequently increased the accuracy (using the app's own settings). No other participant mentioned doing this.

Two participants (#8, Tier 3; #18, Tier 3) reported difficulties in locating the patient. Participant #18 was unsure if this was because of erroneous data given during the 999 call or because of an error originating from the GoodSAM app itself, as an ambulance did not arrive at the location at any time.

No participant reported any issues gaining access to the patient when they arrived first. However, eleven participants arrived after the ambulance service on their most recent alert. Three participants (#14, Tier 1; #17, Tier 2; #25, Tier 1) reported this on earlier alerts, despite responding promptly:

“The vast majority of times I've been activated I have accepted. Every time bar one, by the time I've arrived there's already ambulance personnel there, and have appeared to have been there for some time.” (#14, Tier 1)

Five participants (#5, Tier 1; #16, Tier 2; #22, Tier 1; #23, Tier 1; #24, Tier 3) reported occasions when they were able to provide assistance to LAS:

“Once he realised the level of training that I have he was very excited about the fact that I was there.” (#22, Tier 1)

Three (#15, Tier 3; #17, Tier 2; #23, Tier 1) reported occasions when LAS indicated that they did not require assistance. Two participants (#14, Tier 1; #23, Tier 1) additionally reported that ambulance personnel were cautious about letting them help, particularly without identification:

“Because I've very much found, you know nothing wrong with it necessarily, even if I have arrived and sort of seen paramedics, the ambulance service are not massively receptive to people turning up, not in uniform, who they don't know – which is, I understand to a degree.” (#14, Tier 1)

There were sometimes difficulties adequately explaining the role of a GoodSAM responder:

“I did have a little trouble trying, a little trouble, about 30 seconds convincing them who I was.” (#17, Tier 2)

Five participants felt that a means of identifying oneself as a GoodSAM responder, or a standard set of words (#9, Tier 3), would be useful. Three participants (#23, Tier 1; #24, Tier 3; #28, Tier 1) commented on the importance of informing the ambulance service about your skill level:

“I usually clarify... as an introduction of what my clinical skill level and what I can bring to the situation is. ‘Yeah, I’m a responder on GoodSAM’ but then they want to know what can I give, what kind of interventions can I give, what can’t I.” (#24, Tier 3)

Three participants reported on effective interactions with bystanders on scene. In one case, a relative of the patient realised that the GoodSAM responder was a neighbour (#9, Tier 3) and two LAS employees (#11, Tier 2; #30, Tier 2) clarified with bystanders that, although they were off-duty, they had a professional role with the ambulance service.

Participant #3 (Tier 2) obtained a public-access AED from their workplace before proceeding to the patient during the most recent alert. Participant #30 (Tier 2) found an AED already on the scene, attached to the patient. Three participants owned their own AEDs and had taken them to the scene during their most recent alert.

Eight participants reported no public-access AEDs that they considered to be close enough to retrieve when they accepted a GoodSAM alert. Seven participants were concerned about how they would find and negotiate for the removal of an AED from a certain area:

“There’s a whole rigmarole, can I have a defibrillator, I’m a GoodSAM responder, are these people going to know?” (#17, Tier 2)

Participant 21 (Tier 3) expressed a contrasting view:

“I kind of imagine if ever an organisation or a building or whatever has an AED and you ran in, you said somebody’s having a cardiac arrest can I borrow your AED, I don’t imagine that many people would say no.” (#21, Tier 3)

Two other participants (#26, Tier 1; #30, Tier 2) believed that finding an AED’s exact location would be difficult. Participant 26 was unsure how one would retrieve an AED that was kept in a code-locked cabinet (which many are), and whether or not this code would be available through the app. Contrastingly, two participants (#5, Tier 1; #13, Tier 2) believed that AEDs would not be too difficult to find:

“I think most of them are fairly easy accessible, I think they generally have to be in well-located places and easy to find.” (#13, Tier 2)

Four participants said that there are fewer public-access AEDs available out-of-hours:

“The problem is that I can’t access them at the times that I’ve been notified...they’re in GP surgeries or local shops and both of the times I’ve responded they’ve been out-of-hours.” (#12, Tier 3)

Participants made several suggestions when asked if there was something that could make it easier for them to retrieve an AED. Six participants suggested highlighting the location of the nearest AED in the app during an alert. Two participants (#4, Tier 3; #9, Tier 3) further proposed a system of identifying which AEDs were actually available at the time of the alert.

LAS, however, decided not to record availability hours of AEDs accredited with them. These AEDs do appear on the GoodSAM platform. The principle is that if there is enough resource then it may be appropriate to send someone to see if an AED is available regardless of presumed restrictions. For example, an AED in a locked office building may be available out-of-hours if a night security guard is able to grant access to it. (Key Informants)

Three participants (#1, Tier 1; #16, Tier 2; #19, Tier 3) suggested a more formal link between AED owners and the GoodSAM scheme, thus allowing public-access AEDs to be dispatched *to* the scene, rather than a GoodSAM responder retrieving it.

### **8.4.3 Motivation**

#### *Automatic Motivation*

Seven participants reported anxiety about what they were going to find on the scene:

"Yeah, so, there is an element of anxiety or worry about essentially this random person rocking up to say, 'hi I can help'" (#22, Tier 1)

This anxiety including dealing with patients who had not sustained an OHCA (#6, Tier 2; #10, Tier 2; #17, Tier 2; #25, Tier 1):

"I suppose if there was like mental health issues, or drugs and alcohol involved, I would be a bit apprehensive like getting involved in that" (#6, Tier 2)

Participant #29 (Tier 1) did not respond to their most recent alert and did not think they could "really bring much" to the situation because of the patient's proximity to the nearest hospital.

Three participants (#8, Tier 3; #14, Tier 1; #23, Tier 1) expressed concern about what had happened to a patient when they did not accept an alert:

"I did have that real nagging feeling afterwards about 'oh my god, you know, that person could've died because I didn't go" (#14, Tier 1)

Participant #8 (Tier 3) was a taxi driver who tried to explain to a customer that they had just received a GoodSAM alert. Ultimately, they did not accept the alert and respond, but changed their future behaviour as a result:

"I took him on his journey but immediately felt guilty... So what I've decided for the future, if it goes off again, the passenger will either have to come with me or he'll have to get out. Because the feeling of guilt was more so than letting the passenger down." (#8, Tier 3)

Three participants (#12, Tier 3; #14, Tier 1; #16, Tier 2) reported that difficulties interacting with the app when accepting an alert contributed to their anxiety:

"It's already quite intimidating, but then to have this app that you also don't know how it works, or who you're supposed to be communicating with, that's adds on it." (#12, Tier 3)

Three participants (#15, Tier 3; #20, Tier 1; #30, Tier 2) suggested that equipment provision would be helpful, although all three said that a lack of equipment had not and would not prevent them responding.

Two participants (#6, Tier 2; #28, Tier 1) said that they would welcome incident feedback, or a "debrief" with LAS or the 999 operator (#9, Tier 3). Participant #2 (Tier 3) said they thought people might forget about GoodSAM if alerted infrequently, and telling GoodSAM responders "this amount of alerts had happened" in a given period of time could keep them interested.

### *Reflective Motivation*

Nine participants said that GoodSAM was an important initiative. Three (#6, Tier 2; #9, Tier 3, #16, Tier 2) expressed the belief that it has already saved lives:

“Getting defibrillators to patients and getting people starting CPR early is brilliant, you know, and they’re getting some good results from it already.” (#16, Tier 2)

Participant #19 (Tier 3) said they promoted GoodSAM use when delivering accredited CPR training, and thought making promotional material freely available to CPR trainers would incentivise others to register.

Two participants expressed the belief that the system deliberately activated to serious but non-OHCA cases:

“I end up dealing with tend to be hitting the red flags on the triaging side, but they are definitely aren’t in cardiac arrest.” (#10, Tier 2)

“I mean, whether we’re there just to press on scene, you know, just to save the ambulance service getting a fine, I don’t know.” (#17, Tier 2)

A number of factors affected or would affect a GoodSAM responder’s intention to accept an alert. Distance to the instance was cited by eleven participants:

“How far away it is, because if there’s no reasonable chance I can get there, you know, within a decent space of time then that would affect it [my decision].” (#12, Tier 3)

Six participants reported a belief that ambulance personnel would get to the scene before them, reinforced by previous experience:

“I find that very frustrating, because you drop what you’re doing, go and assist someone and then by the time you get there there’s already enough people so you just kind of not go. So that is another reason that potentially I wouldn’t go because you make an assumption thinking that actually there’ll be people there by the time I get there.” (#14, Tier 1)

Participant #9 (Tier 3) reported responding to an alert at 0230hrs in the same block of flats as them, but five others participants reported not accepting alerts because they occurred overnight:

“If it’s late at night I would feel a little bit vulnerable about going out into the streets in my pyjamas at 1am, so I might not respond very late at night.” (#18, Tier 3)

Participant #30 (Tier 2) reported being informed by the app about other GoodSAM responders accepting or rejecting the same alert, but did not believe this had or would affect their decision to respond:

“I’ve had a few before where it’s come through that more than one person was going but I still sort of go down there.” (#30, Tier 2)

Twenty participants stated a preference for going directly to the patient to assess the situation and provide CPR, rather than retrieving an AED first. Once on scene, the task to retrieve an AED could be delegated:

“Because that [an AED] obviously makes a massive difference to early survival, but I think I would deem somebody doing good-quality chest compressions as a higher priority than taking an extra five to ten minutes to find the local machine.” (#26, Tier 1)

“I know that in my area you’re likely to get an ambulance or at least a fast response car very quickly so getting there and doing effective

bystander CPR probably'd be more effective and then when the crew turns up put the defib straight on." (#5, Tier 1)

Participant 19 (Tier 3) commented on the negotiation for an AED from its custodian:

"I wouldn't waste too much time if there was questions of 'who are you, why do you want it' etc. If I couldn't get it immediately within 5 to 10 seconds I would be on my way without it." (#19, Tier 3)

Seven participants commented on the importance of early AED use to survival, and three (#10, Tier 2; #18, Tier 3; #20, Tier 1) believed they would try and get an AED first if possible:

"If at all possible, that's the best way to save their life really. It would be worth the extra minute, or the extra, to get the defibrillator first." (#18, Tier 3)

Three participants (#13, Tier 2; #17, Tier 2; #21, Tier 3) talked about the uncertainty about whether or not to retrieve an AED first:

"I appreciate obviously getting an early shock as quick as possible is preferable for the patient but equally I would feel bad if there was someone not doing any compressions and I had to spend five minutes trying to find a defib." (#13, Tier 2)

Participants also commented that additional information during the GoodSAM alert might affect the decision to respond to an alert (#13, Tier 2; #23, Tier 1) or to retrieve an AED (#4, Tier 3; #20, Tier 1; #25, Tier 1). One participant said that the information received in the GoodSAM alert had actually influenced the decision not to retrieve an AED first:

"On this occasion, did you get an AED, did you take an AED to the scene?" (Interviewer)

|  
“No, I didn’t, because it was reported as a breathing obstruction.”  
(#4, Tier 3)

Thirteen participants reported that their intention to retrieve an AED would be affected by its proximity to the patient or the route taken to the scene:

“You know if it involves me going a long way out the way I can always get there [to the scene] and while I’m doing CPR send someone else off to get it. But if it’s on the way through then I’d grab it on the way.” (#15, Tier 3)

Participant #23 (Tier 1), who passed but did not retrieve an AED on the way to an alert, indicated the intention to do so in future based on their experience:

“I didn’t know whether it was worth it, and I’d probably hadn’t thought about it as carefully as I, I just thought well I don’t have an AED, but I can do bystander CPR... Now I’m much more likely.” (#23, Tier 1)

Five participants said they had planned ahead by finding AED locations on the GoodSAM app before receiving an alert. Participant #22 (Tier 1) reported that they looked up AED locations every time they went to a new area.

Participant 21 (Tier 3) reported that a lack of belief in their own abilities had stopped them responding, but did feel confident using an AED if they did reach the scene:

“I’ve never actually given CPR or any of those kind of emergency first aid procedures on a real person...there’s a lack of confidence in, you know, my abilities, even though actually I have no reason to doubt my abilities...all the training AEDs I’ve seen have been really explicit in their instructions, so I wouldn’t have any concerns with just picking one up and using it.” (#21, Tier 3)

Seventeen participants explicitly expressed confidence in AED use. Reasons given were previous training (#15, Tier 3; #18, Tier 3), previous real-life experience (#3, Tier 2; #6, Tier 2; #10, Tier 2; #11, Tier 2) and perceived ease of use (#11, Tier 2; #15, Tier 3; #18, Tier 3). Participant 23 (Tier 1) acknowledged that unfamiliarity with a particular brand of AED would be a challenge, but one that could be overcome:

“I’d be more likely to struggle with an automated one than with a manual one but I think I could work it quite effectively even if I hadn’t seen the model before.” (#23, Tier 1)

There were also concerns about managing people and the scene, including one participant who commented on how this might affect AED use:

“Yeah I would be able to do that [use an AED], I think 90%. My, the hesitancy would be about dealing with the patient and the people around them. To suddenly say right we’ve got to get this top off and I need to connect these things straight away... So, let’s say 80% confident that I would do so.” (#9, Tier 3)

Three participants (#22, Tier 1; #24, Tier 3; #28, Tier 1) remarked that their sense of professional duty affected their motivation to respond to an alert:

“It’s also what I do as a first-responder, I’m a St John Ambulance first-responder, and I used to work rescue, so it’s somewhat a large portion of what I do and who I am, so there’s not many situations where I wouldn’t want to respond to.” (#24, Tier 3)

However, three Tier 1 responders (#5, #22, #23) stated concern about intervening outside their usual environment:

“It was a little bit more nerve-wracking because you walk in and you’re like I want to do this, this and this but actually I can only do CPR.” (#5, Tier 1)

“I don’t know how I would manage the crowd or anyone who was going hysterical next to the patient... If I’m the only one trying to do all of that I might find it quite overwhelming, but until I’m in that situation, I’m not really sure.” (#22, Tier 1)

Five participants expressed concerns about how the ambulance service would respond to them as a bystander stating that they had previous healthcare or first-aid experience.

## **8.5 DISCUSSION**

### **8.5.1 Main findings**

In almost all cases participants reported confidence in their capability to respond, provide CPR and use an AED. They sometimes arrived after the ambulance service and were still able to provide assistance.

Considering their most recent alert, one out of thirty GoodSAM responders retrieved a public-access AED en-route to the patient, and one other used an AED that was already on the scene. Additionally, three other responders brought their own AED to the scene. GoodSAM responders used the app at other times to familiarise themselves with the location and access hours for public-access AEDs.

Slow-loading screens, responder location inaccuracies and confusion about some of the app’s functions potentially increase anxiety and reduce motivation to respond to future alerts.

Motivation to respond to future alerts could also be affected by: a belief that the ambulance service would arrive first – borne out by previous experience – and finding patients who had not sustained an OHCA.

Whilst knowledgeable about PAD and motivated to use a public-access AED, GoodSAM responders saw poor location and accessibility of public-access

AEDs as barriers to successful deployment. There was concern about the additional time taken to retrieve an AED and not knowing whether or not bystanders were performing CPR during this time. Knowledge of specific public-access AEDs and an ability to retrieve it without diverting too far from their route to the patient could facilitate AED retrieval.

### **8.5.2 Comparison with the literature**

My recent systematic review ([111](#)) considered barriers and facilitators to PAD amongst all bystanders, and its findings supported the view expressed by several participants in this study that previous training in CPR and AED was associated with increased knowledge about AED function and location, and reported willingness to use an AED. The Danish 'Hearrunner' system liaised with the global 'Restart a Heart Day' ([106](#)) in 2017, where co-ordinated sessions train as many people as possible in CPR and the use of an AED. They subsequently reported a big spike in new people registering on their app (personal communication, F Lippert).

The systematic review ([111](#)) also reported that few OHCA occurred within 100m of an AED, and their accessibility was reduced out-of-hours. In the current study, participants often reported that AED locations were not sufficiently close to them or the patient for them to consider retrieving one, or that they were inaccessible at the time of the alert.

GoodSAM responders reported anxiety about scene management, uncertainty about what they would find on scene and concern about patient outcome when rejecting an alert. Zijlstra and colleagues interviewed 203 volunteer first-responders in the Netherlands (2013–2014) who had reached an OHCA patient first, after responding to a text-message alert. Of these, 189 completed an online questionnaire shortly after the event examining short-term impact, and a validated 'Impact of Event Scale' assessment four to six weeks later. Short-term impact was reported as 'none/mild' by 78 (41%), 'bearable' by 87 (46%) and 'severe' by 24 (13%). On the Impact of Event Scale assessment, all of the volunteer first-responders reported either no stress

(81%) or mild stress (19%). There was an association between not attaching an AED to a patient and the volunteer first-responder experiencing mild stress four to six weeks after the event (262).

In this study, three participants reported a desire for incident feedback or debrief. In the 'Hearrunner' system volunteer first-responders accepting alerts receive a questionnaire via the app within 90 minutes, including questions on any psychological issues. Those scoring highly on the rating scale that is used are offered formal follow-up and debriefing (personal communication, F Lippert). Debriefing of bystanders after an OHCA can provide positive short-term effects that persist for at least two months (335).

There are limited patient outcome data from volunteer first-responder systems. More research like I have conducted in this study is needed to investigate how we might optimise the volunteer first-response. The Scandinavian AED and Mobile Bystander Activation (SAMBA) trial (183) aims to randomise 490 participants responding via the Hearrunner app to either a group where all responders are directed to go to the patient and start CPR or a group where some responders retrieve the nearest AED first. The primary outcome is the proportion of patients who have an AED attached before the arrival of the ambulance service.

### **8.5.3 Strengths and limitations**

I conducted semi-structured interviews using a topic guide focussing on decisions to respond and to use a public-access AED during an alert. Issues that emerged during early interviews were incorporated into the topic guide for later interviews. On analysis of the interview transcripts I realised there were issues that I did not always explore in detail, including reasons participants perceived they could not remove themselves from their current situation. I could also have explored differences between 'out-of-hours' (e.g. late at night, weekends) and 'in-hours' alerts.

The original intention was to interview participants about their most recent alert: it was anticipated that interviews would share many features with a retrospective verbal protocol analysis (336), encouraging interviewees to 'think aloud' about the choices that they have made (337). This strategy is well-recognised in usability testing (337,338) when a new system or process is being evaluated for ease of use. Conducting the interviews shortly after the event would allow for an accurate retelling of events (328),(329).

However, it soon became apparent that all of the participants had received multiple GoodSAM alerts, and had both accepted and rejected at least one of these alerts in almost all cases. Experiences from all of these alerts were relevant to this study. Participants were encouraged to talk about their most recent alert first before discussing pertinent issues arising from earlier alerts.

A public-access AED was taken to the scene on only one occasion, so much discussion around AED use was about what participants said or believed they would do in a given situation. However, stated intentions might be different to actual behaviour. It can be difficult to predict what people will actually do in a high-stress environment which require time-critical decisions with limited information (339,340). Asking participants to provide opinions about what would make it easier for them to both respond and retrieve a public-access AED in the future might itself, inadvertently, have prompted a future change of behaviour among the participants.

People may also rationalise their actions (337,341). This study attempted to mitigate this by emphasising in the Participant Information Sheet that the process was not intended to make judgements on the decisions they made, only to understand what might make these decisions easier in the future. The sense of anonymity granted by telephone interviews might help participants provide more complete and honest answers when dealing with sensitive issues (327). This approach was used in recent research of resuscitation actions by lay bystanders, with researchers concluding that it allowed a degree of privacy and security to the interviewee whilst allowing the researchers to gather information in reasonable proximity to the sensitising event (268).

Judging which information should have been coded to a particular theme was subjective (342), particularly as I used an existing framework with pre-determined themes (194). I had tested the suitability of the TDF for this data by coding the first three interviews without reference to any existing framework and then determining how well we thought the TDF would capture the themes that arose. Confidence in using the TDF for all remaining interviews was increased because I was examining a well-specified target behaviour in a reasonably homogenous and defined population (185).

Researchers who developed the TDF recommend not coding information that does not fit into one of the domains (185). There was a very small amount of information coded in this interview study that did not fit into a specific TDF domain. These were mainly technical problems with the app and were reported to GoodSAM for the purposes of quality improvement, as they may affect responders' opportunities to respond effectively.

Following the end of the study period, GoodSAM subsequently discovered that there was a 1-4 minute delay to GoodSAM activation in London after allocation of an OHCA code by the 999 call-handler. The reasons for this were not known, but will clearly have reduced the opportunity for a GoodSAM responder to arrive before the ambulance service. GoodSAM and LAS have now rectified this error, and GoodSAM is activated as soon as an OHCA code is allocated.

The Key Informant interviews were less important than initially anticipated. My own understanding of the app process improved substantially during the study period, and there was already substantial expertise in the app and its use in London among the PhD project steering group. The TDF was used to classify key findings from these interviews but was perhaps a blunt tool for this job. Most of the findings related to technical and organisational aspects that affected the opportunity to use the app effectively, which mapped to those TDF domains that link with 'Opportunity' in the COM-B model.

The final nine interviews were conducted after the first 21 had been transcribed and coded. This allowed me to review the topic guide and renew the focus on

topics that perhaps should have been prioritised more in earlier interviews. In particular, I was able to probe more about what specifically affected the decision not to respond to the most recent alert. I further explored responder emotions, such as self-doubt or confidence, which might have influenced their decision not to respond. For those with healthcare training, this included discussions about acting in a bystander role rather than a professional one.

In recruiting for the final nine interviews, GoodSAM sent out invitations only to responders who had rejected their most recent alert. This targeted selection in our second recruitment window also inadvertently placed a higher value on reasons for rejecting alerts rather than accepting them, reducing opportunities for the study to identify important facilitators.

Despite attempts to make the interview sample representative with regards to alert acceptance or rejection, it is possible that the recruited participants are not representative of all GoodSAM responders. Those who participated might represent a group of GoodSAM responders who are more confident in their abilities and more motivated to respond to an alert. As such, they might be more willing to consent to interview.

The method of recruitment to the study – via e-mail, with no follow-up of non-responders – meant that I could not assess the attributes of those who did not participate when invited ([195](#)). Recruitment may be more difficult when dealing with a sensitive topic ([327](#)) and those that do respond may be prone to ‘social desirability bias’ – being more likely to report what they think the interviewer wants to hear, motivated by a desire to avoid embarrassment or censure from a third party ([343](#)).

In this study, only one participant (#21, Tier 3) expressed under-confidence and self-doubt that prevented acceptance of an alert. It is important not to disregard this ‘dissenting’ view as it may be shared by a number of other GoodSAM responders who did not respond to the interview invitation.

This was a PhD project and so I conducted the interviews and was primarily responsible for transcription, coding and analysis. I am a novice qualitative researcher and interviewer and there were certainly occasions when, on transcribing audio recordings, I recognised follow-up or probing questions that I could have subsequently asked at the time but did not. My inexperience was mitigated by regular senior support (FG). There were regular checks and feedback about interview transcripts, question focus and coding approach, which were updated if appropriate.

Additionally, I have clinical expertise relating to cardiac arrest management and, as an Emergency Medicine doctor, substantial experience of talking to people about sensitive topics in difficult situations. My role in this interviewer was as an academic researcher, not a clinician, and I attempted to make this clear during the interview process. Nevertheless, it is possible that knowledge of my clinical role may have affected the way in which participants responded to my questions (322).

Qualitative researchers recognise that it is difficult to collect information without some form of bias or subjective judgment intruding on the process (190). I was cognisant that what the GoodSAM responder was telling me sometimes contrasted with my own knowledge or opinions about OHCA priorities or how GoodSAM worked. It is important for the interviewer to recognise and reflect on how their personal attributes might affect the interview process and lead to assumptions about the data being collected (327). To help mitigate this, the interview schedule had written reminders about interview conduct. The overriding principles were to be non-judgmental at all times and to not guide the interview by imposing my own opinions about what the best course of action would have been during a particular GoodSAM alert.

#### **8.5.4 Clinical implications**

The use of public-access AEDs before the arrival of the ambulance service can improve survival from OHCA (69), but infrequent use of AEDs will hamper improvements in survival at a population level.

Among the 30 GoodSAM responders who participated in interview – many talking about their experiences from several alerts – only one reported retrieving a public-access AED. I identified a number of barriers, but I think the concern about whether or not CPR is being performed on scene (and the consequences of delaying CPR) stands out.

This may mean that interventions to improve AED use during a GoodSAM alert are more likely to be effective when the person toward whom the intervention is targeted knows that someone else is available to go to (or is already at) the scene to start CPR. The opportunity to retrieve an AED also requires the GoodSAM responder to first accept the alert. Thus, to effectively increase AED use one must also find the means to increase the number of responders on the GoodSAM platform, and to facilitate them accepting an alert.

#### **8.5.5 Next steps**

GoodSAM and other volunteer first-responder systems have the capacity to provide an OHCA patient with both a CPR-capable responder and access to an AED. In the next chapter I will describe how the barriers and facilitators identified in this chapter were the starting point to identify how relevant behaviours could be changed to improve AED use in the system.

I did this by following behavioural change processes outlined in the Behaviour Change Wheel (199). This resulted in a list of potential interventions for discussion with stakeholders – including GoodSAM, ambulance services and patient groups – to identify which would be most appropriate for further investigation.

### **8.6 CONCLUSION**

GoodSAM responders used public-access AEDs infrequently. Despite a capability and motivation to use them, participants perceived a lack of opportunity to do so. Those with access to their own AEDs reported taking them to scene when accepting an alert. Most believed going to the patient first

to assess CPR provision was more beneficial to the patient than diverting to retrieve an AED first. Perceptions about delays to and ease of public-access AED retrieval, and previous experiences of arriving after the ambulance service or finding a patient who had not sustained an OHCA influenced this decision.

# CHAPTER 9

Developing theoretically-informed  
interventions to improve Automated  
External Defibrillator use by  
GoodSAM first-responders

---

**Part of this chapter has already been published (189):**

**Smith CM**, Griffiths F, Fothergill RT et al. Identifying and overcoming barriers to automated external defibrillator use by GoodSAM volunteer first responders in out-of-hospital cardiac arrest using the Theoretical Domains Framework and Behaviour Change Wheel: a qualitative study. *BMJ Open* 2020;10:e034908

---

## **9.1 INTRODUCTION**

A GoodSAM responder received an alert for a nearby out-of-hospital cardiac arrest (OHCA) in a minority of cases in London (2016–2017). Fewer still accepted an alert (i.e. agreed to go to the scene to offer assistance), and multiple acceptances occurred in only 3/4196 (0.07%) OHCA (**see Table 6.1, chapter 6**). In the interview study (**chapter 8**), a GoodSAM responder reported retrieving a public-access Automated External Defibrillator (AED) during a GoodSAM alert on only one occasion.

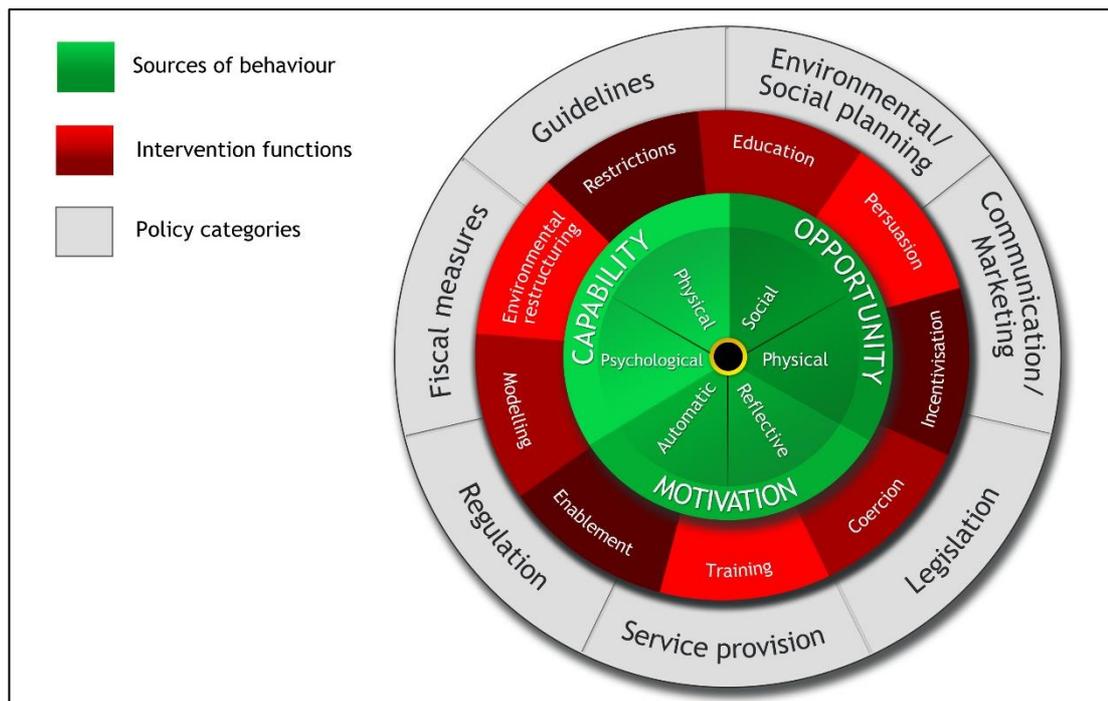
A patient who has ventricular fibrillation or ventricular tachycardia (VF/VT) as the underlying cardiac rhythm during cardiac arrest might benefit from prompt defibrillation. Those with pulseless electrical activity (PEA) or asystole will not, and prompt cardiopulmonary resuscitation (CPR) is a better option. There are no validated models that predict the cardiac rhythm at the point of collapse, so one cannot know the correct strategy for a GoodSAM responder – i.e. retrieve an AED first, or go directly to the patient. Interventions to increase AED use by GoodSAM responders would not be appropriate if they compromised patient outcomes by substantially increasing the time to first CPR.

A GoodSAM responder cannot even consider retrieving an AED during an OHCA response if they do not first accept the GoodSAM alert. Effective interventions to increase AED use by GoodSAM responders may require an increase in the number of people registered with GoodSAM (and able to receive an alert), and efforts to increase alert acceptance rates.

I classified barriers and facilitators to AED use by GoodSAM responders (**chapter 8**) using the Theoretical Domains Framework (TDF) (196). The TDF links to the COM-B (Capability, Opportunity, Motivation) behavioural framework (198), which identifies targets for behavioural change. The COM-B model integrates in turn with the Behaviour Change Wheel (BCW) (199), which provides a method to develop and implement interventions to change behaviour.

## 9.2 AIM

The aim in this chapter was to develop a list of evidence-based, theoretically-informed interventions to increase public-access AED use in GoodSAM responders alerted to a nearby OHCA, using the BCW (199).



**Figure 9.1: The Behaviour Change Wheel. From Michie et al (199), p18**

## 9.3 METHODS

### 9.3.1 Information sources

Barriers and facilitators related to Capability, Opportunity and Motivation (**chapter 8**) and the fact that a low proportion of OHCA had GoodSAM alerts and alert acceptances (**chapter 6**) were the starting point from which I have developed a list of potential interventions.

### 9.3.2 Using the Behaviour Change Wheel

I used an eight-step process suggested by the authors of the BCW ((199), Figure 2, p25) to construct a list of potential interventions – for future testing – to improve AED use in GoodSAM responders.

The eight steps listed below took account not only findings from interviews (**chapter 8**) but also, where appropriate, evidence from the literature. I reviewed behaviour change theories and searched for existing evidence on the effect of factors affecting capability, opportunity or motivation to participate in OHCA resuscitation in a bystander or ‘good Samaritan’ role

When developing interventions to overcome complex behaviours there is often the need for individual judgement (199). I exercised such judgement with input from project supervisors where appropriate.

#### Step 1: Define the problem in behavioural terms

This required an identification of the problem of interest, an examination of the behaviour required to overcome the problem, and an identification of the specific group of people who must perform the behaviour. I have drawn predominantly on the interview findings.

### Step 2: Select target behaviour

I identified the key behaviour to target for change, and any related behaviours that might impact upon it.

### Step 3: Specify the target behaviour

I considered the behaviour in as much detail as possible, including the context within which this behaviour was performed. I reported who performed the behaviour, when, where, how often and with whom, and what they needed to do differently to effect the outcome of interest.

The BCW suggests considering the following when judging the appropriateness of the selected behaviours:

- What is the impact of changing behaviour on the outcome of interest?
- What is the likelihood of changing the behaviour? – considering the capability, opportunity and motivation of those performing the behaviour
- Will the behaviour have an impact on related behaviours?
- How easy will it be to measure the behaviour?

One should then determine whether the target behaviour is:

- **Very promising** as a target behaviour;
- **Quite promising** as a target behaviour;
- **Unpromising but worth considering** as a target behaviour, or;
- **Unacceptable** as a target behaviour

### Step 4: Identify what needs to change

I identified whether or not there was a need for change, and what needed to change in the person performing the behaviour or in their environment. I detailed this using the Capability, Opportunity or Motivation components from

the COM-B model. The COM-B components can be further divided into physical capability and psychological capability, physical and social opportunity, and reflective and automatic motivation (198).

I referred back to findings from the interview study and any other relevant research, but this process relied substantially on my judgement to determine if a change was needed.

#### Step 5: Identify intervention functions

There are nine intervention functions in the BCW: education, persuasion, incentivisation, coercion, training, restriction, environmental restructuring, modelling, and enablement. Each component of COM-B links to at least two of these intervention functions: e.g. one can change behaviour by improving *psychological capability* by means of *education, training or enablement*.

For each of the target behaviours identified in step 4 where I identified that there was a need for change, I assessed the feasibility of using an intervention function to effect this change using the APEASE criteria (see (199), p23)

- **Affordability:** can you deliver the intervention to the target group within budget?
- **Practicability:** can you deliver the intervention *as designed* to the target group?
- **Effectiveness/cost-effectiveness:** what is the effect size of the intervention, and how does this relate to cost?
- **Acceptability:** How appropriate do all relevant stakeholders think that the intervention is?
- **Side effects/Safety:** If the intervention is effective, what are the side-effects or other unintended consequences?
- **Equity:** Will the intervention affect differences in health and/or wellbeing that already exist between groups in society?

I considered interventions that could be delivered by GoodSAM responders by using the GoodSAM app, facilitating use of the app or modifying the function of the app.

Some of the information provided in the results for this section relied on my existing knowledge of the app's capabilities and how it could be changed.

#### Step 6: Identify policy categories

There are seven policy categories in the BCW: communication/marketing, guidelines, fiscal, regulation, legislation, environmental/social planning, and service provision. These are the types of decisions made by responsible or authority figures and each of the policy categories in the BCW are expected to support the delivery of two or more of the intervention functions (see (199), p138).

#### Step 7: Identify behaviour change techniques

This concerned identification of a relevant 'behaviour change technique', which is the specific content (or component) in an intervention that is required to change the behaviour in question. These components should not be further subdivided and may be used in isolation or in combinations with others.

The BCW suggests the most commonly used behavioural change technique for each of the intervention functions. It uses the 'Behaviour Change Technique Taxonomy version 1' (BCTTv1), which collects 93 components into 16 groups (344).

#### Step 8: Identify mode of delivery

This concerned how to deliver the behaviour change technique(s) and thus the intervention – e.g. face-to-face or remote; at individual or group level; using a variety of media (see (199), p177)

### 9.3.3 Ethical approvals

The BSREC at the University of Warwick granted ethical approval on 16<sup>th</sup> March 2018 (REGO-2018-2164).

## 9.4 RESULTS

### 9.4.1 Step 1: Define the problem in behavioural terms

The outcome of interest was increased public-access AED use by a GoodSAM responder during an alert about a possible OHCA.

The group of interest is registered GoodSAM responders that have downloaded the GoodSAM app onto their mobile devices, and it is their behaviours that I am focussing on. I have not considered wider policy decisions by GoodSAM, such as how to get more people to register with the app.

Bystanders use public-access AEDs before the arrival of the ambulance service infrequently. In 2018, it happened in 4.5% of OHCA patients for whom resuscitation was attempted in England (12). This is relevant as it is associated with a doubling in both survival to hospital discharge and survival with a favourable neurological outcome (69).

Interview findings (**chapter 8**) similarly suggest that AED use by GoodSAM responders is infrequent ('the problem'). However, from the moment of a patient's collapse the chance of surviving an OHCA decreases by about 10% per minute without any intervention (345). It is therefore often difficult to know whether to prioritise early CPR or early defibrillation – and there is no way to know whether defibrillation is indicated at all until the AED is attached. To my knowledge, there is no published literature assessing how volunteers responding to a remote patient make this difficult decision. Indeed, there is no certainty at the time of alert acceptance that the patient actually has sustained an OHCA.

Using findings from the interview study (**chapter 8**), I have listed the sequential behaviours and decisions required for a GoodSAM responder to successfully use an AED during an OHCA response. Here, I define 'use an AED' as the correct attachment of the AED to the OHCA patient so that the AED can determine whether or not to provide a shock.

**KEY:**

- **Action required**

- Decision or behaviour leading to action

- **Have the app active on their phone**

- Once installed, the GoodSAM responder should be logged in. Once they are, the GoodSAM app will always be on in the background

- **Hear alert siren**

- Ensure mobile phone is **not** be on silent mode *or*;

- Set-up app to 'override silent' (the alert siren will sound even if the phone is on silent mode)

- Realise that the alert noise is coming from their phone (ideally, already know what the alarm sounds like) and open up the app (requires single button press) in response to this

- **Accept the alert**

- Judge that they are able to or 'allowed' to leave their current situation (considering work commitments, personal commitments, dependents)

- Wish to leave their current situation (considering the convenience of leaving their current activity and/or location)

- Judge that it is safe to travel to the scene (considering knowledge of the local area, time of day/night)

- Believe that performing CPR +/- using an AED before the ambulance arrives may make a difference to the patient's outcome

- Believe that they will be able to locate and gain access to the patient

- Believe that they can arrive at the patient's side before the ambulance service (based on perception of ambulance response)

time, their own distance from and estimated travel time to the patient, travel modality available to them and travel modality they judge appropriate to use) *or* that they can offer meaningful assistance if they arrive after the ambulance

→ Believe that the alert is likely to concern a patient with confirmed OHCA (based on their previous experience – and knowledge of others' previous experience – of responding to non-OHCA incidents)

→ Judge that they are physically capable of providing assistance at the time of the alert (considering physical impairments/injuries that may stop them travelling to scene, alcohol consumption)

- **Take their own AED with them *if they have one***

→ Have it available or close enough to them at the time of accepting the alert (for example, in own vehicle or own home)

→ Have it close enough to them and remember to retrieve it when leaving to travel to the OHCA patient

- **Be aware of a public-access AED *if they do not have their own available***

→ Know about or have training about the function, likely location and use of an AED

→ Be aware of a nearby AED(s) and its location, and spontaneously think about retrieving it at the time that they accept an alert *or*,

→ Notice the location of a nearby AED displayed on-screen in the GoodSAM app at the time of an alert

- **Decide to retrieve an AED en-route to the OHCA patient**

→ Believe it is practical to do so (requiring judgement of distance and time to both the patient and the AED, and the patient/AED's relationship to each other and to them – i.e. is it 'on the way')

→ Believe that an AED may be necessary on scene – i.e. do they believe it might be a confirmed OHCA with no other AED already present

→ Believe that using an AED may make a difference to outcome on this occasion

- Judge the added time required to retrieve the AED compared to going directly to the patient, and the (potentially beneficial, potentially adverse) effect of doing this
- Believe that they will be able to locate and remove the AED from its location in a timely fashion
- Believe that they will be able to get to the patient's side before the ambulance if they divert to retrieve an AED first
- **Be able to locate the public-access AED**
  - Know what an AED looks like and how they are displayed
  - Need a visible AED and/or location sign(s)
  - Have previous knowledge of its location *or*,
  - Need an accurate location via the app – displayed in the map on-screen, and/or a sufficiently detailed location description
- **Be able to remove the public-access AED from its location**
  - Need to be able to gain access the AED's location
  - Need to have an unlock code if the AED is in a locked cabinet *or*,
  - Need an AED's guardian (for example at a sports centre or business location) to locate and grant the GoodSAM responder permission to remove the AED to a remote location
- **Be able to find and access the patient**
  - Need an accurate incident location to be provided during the GoodSAM alert
  - Need unimpeded physical access to the scene
  - Need bystanders/others at the scene to allow the responder access to the scene and the patient
- **Be able to arrive at the patient before the ambulance service arrives**
  - Needs the ambulance response time to be less than the sum of: the time taken for the GoodSAM alert to reach the responder's phone after diagnosis of a potential OHCA and the initial dispatch of the ambulance during a 999 call, the time taken for the responder to recognise and accept the alert, the responder's travel time to the incident, and the time taken to reach the patient's side once there.

- **Be able to use the AED appropriately**
  - Know the correct indications for AED use (i.e. apply to the unconscious patient who is not breathing normally (6))
  - Judge that these indications exist for the current patient
  - Know about the AED function and/or be able to operate the AED by following the voice prompt instructions
  - Have the confidence to use the AED

#### **9.4.2 Step 2: Select target behaviour**

The target behaviour in a GoodSAM responder is *'retrieval of a public-access AED en-route to a patient when responding to a GoodSAM alert.'*

During the interview process it became evident that this target behaviour is closely related to the behaviour *'accepting a GoodSAM alert.'* The issue of retrieving a public-access AED does not arise if a responder does not decide to accept an alert. As work in this chapter progressed it was also clear that several of the proposed interventions to increase retrieval of a public-access AED would require multiple responders to accept an alert.

Therefore, while retrieval of a public-access AED is the target behaviour I have focussed on in this chapter, I have explicitly considered how the decision to accept a GoodSAM alert interacts with this behaviour.

#### **9.4.3 Step 3: Specify the target behaviour**

##### *The target behaviour in context*

*Who needs to perform the behaviour?*

GoodSAM responders who receive an alert about a nearby OHCA.

### *When?*

On receipt of an alert. This could be at any time, providing that their phone is on (the app runs automatically in the background once it is installed and the GoodSAM responder is registered and logged in) and they hear the alert siren. They must decide to accept the alert and travel to the patient to provide assistance, at which point they also will decide whether or not to retrieve a public-access AED en-route.

### *Where?*

Wherever the responder is when they receive an alert. They will only receive an alert if they are within a certain distance of the OHCA (specified by each local ambulance service).

### *How often?*

On any occasion that they receive a GoodSAM alert. There is no published, available data on the frequency of alerts that an individual responder receives. However, GoodSAM record each alert (and its recipient) so a researcher could obtain this information. Where population density, OHCA incidence and GoodSAM responder density are higher it is reasonable to predict that an individual will receive more alerts.

### *With whom?*

Often alone. It is currently rare for more than one first-responder to accept a GoodSAM alert for OHCA (**chapter 6**). GoodSAM responders are likely to be remote from one another, but there is a facility within the app for responders to send messages to one another. None of the interview participants mentioned having done this and so I have no information from GoodSAM responders about how practical this might be.

If two or more registered GoodSAM responders are together, there is the possibility to collaborate: e.g. one goes directly to the patient and the other goes to retrieve an AED.

*What does the person need to do differently?*

The GoodSAM responder needs to make a potentially time-critical decision when accepting the alert to travel to the site of a public-access AED first. They of course could change their minds en-route to the AED and divert back to the patient. They may also reach the AED location, and be unable to find it, access it or negotiate its release in a timely fashion.

*Appropriateness of targeting this behaviour for change*

*Impact of changing behaviour: quite promising.*

Public Access Defibrillation (69) and CPR (6) each at least double OHCA survival to hospital discharge. However, survival to hospital discharge decreases by approximately 10% per minute without any bystander intervention (345), and there is no published evidence on the best strategy re: AED retrieval strategies for volunteer first-responders. Several interview respondents (**chapter 8**) raised concerns that diverting to retrieve a public-access AED might increase the time that an OHCA patient spends without any intervention being performed at all.

*Likelihood of changing behaviour: quite promising.*

**Capability:** Most interview participants felt capable of using an AED.

**Opportunity:** There was a perceived lack of suitably-located public-access AEDs available when receiving an alert, particularly out-of-hours. A number of studies have reported that public-access AEDs are not accessible at the time of an OHCA (276,278,279), with a substantial out-of-hours reduction in availability (179,181).

**Opportunity:** GoodSAM displays the location of nearby public-access AEDs in the app (at all times when the app is opened, not only at the time of an alert), including written descriptions of the location and hours of access. Interview participants did not always notice whether or not an AED was displayed when they looked at their mobile phone when responding to an alert.

Our working memory is limited, and even a small increase in the number of pieces of information we are presented with can greatly increase how we arrange this information and decide what to do with it. Minimising this increased pressure on our working memory – the so-called ‘cognitive load’ (346) – particularly in times of stress, which itself adversely affects decision making (347,348) – increases the likelihood that one can perform a behaviour or task correctly (346).

**Motivation:** Most interview participants understood the importance of early defibrillation, and believed that it could make a difference to outcome. Researchers in Denmark, interviewing bystanders who had actually intervened in an OHCA (2012–2015), reported that such prior belief was a facilitator to lay rescuer intervention, including AED use (268)

**Motivation:** Interview participants indicated they would be more likely to retrieve a public-access AED if they could be assured that another person was providing CPR. The Theory of Planned Behaviour holds that intentions are directly linked to and precede behaviour. They are partly affected by attitudes towards that behaviour (i.e. is it right to do it in this circumstance?) and how much control one feels they have over the behaviour (349). Not having control over someone else performing CPR (whilst retrieving an AED themselves) is a potential barrier for GoodSAM responders. Reliable information about someone else performing CPR might help overcome this barrier.

*Impact on related behaviours: quite promising.*

**Capability:** GoodSAM responders are a self-selected group with prior resuscitation training. If they retrieve an AED, it is reasonable to presume a

high chance that they will be capable of using it – sufficient experience in a practical skill allows a certain degree of automaticity when subsequently performing that skill (350). However, even CPR-trained bystanders do not always perform CPR when required (351), and throughout the resuscitation literature there is a paucity of evidence linking performance in skills training and quality of performance in actual resuscitation efforts (352).

**Opportunity:** The opportunity to use a public-access AED only arises if a GoodSAM responder accepts a GoodSAM alert, retrieves one en-route to the patient and arrives before the ambulance service. A GoodSAM responder may not use this AED if another bystander at the scene has located and brought a public-access AED to the patient already, with or without assistance from the 999 call-handler.

**Motivation:** Training facilitates self-reported willingness to use an AED (111) and actual AED use in real OHCA (268). It seems likely that trained GoodSAM responders will be able to use a public-access AED successfully if they retrieve one.

**Motivation:** The likelihood of performing a behaviour in the future can be increased by positive experiences ('reinforcement') and decreased by negative experiences ('punishment') – this is a very simple explanation of 'operant conditioning' (353). The experience of retrieving a public-access AED and the impact this has on a GoodSAM responder may affect their motivation to retrieve an AED – and/or to respond to an alert at all – in the future.

Interview participants reported that arriving at the patient after the ambulance service had arrived negatively affected their motivation to respond to future alerts. Bystanders intervening in real-life OHCA found that remembering their CPR skills and believing that their interventions were important increased their motivation to help again in future emergencies (268). In Sweden (1990–1994), 93% of 425 bystanders who took part in resuscitation efforts viewed what they did positively, and 99.5% were prepared to start CPR again (354).

Adverse effects are rare in bystanders (246) and volunteer first-responders (262) intervening in OHCA. In the latter group, in a study from the Netherlands about text-message-activated volunteer first-responders (2013–2014), negative psychological impacts were short-term with all experiencing either ‘no stress’ (81%) or ‘mild stress’ (19%), as measured on a validated ‘Impact of Event Scale’ assessment, four to six weeks later (262). In Copenhagen (2017–2018), 1.4% (22/1624) volunteer first-responders activated by the ‘Hearrunner’ app reported that their psychological health had been ‘severely impacted’ following an OHCA response, and three required professional follow-up (355).

*Ease of measurement: very promising.*

The infrastructure to measure public-access AED use during an alert already exists. GoodSAM app users can complete post-event in-app feedback where they can record whether or not they used an AED. GoodSAM do not specifically ask whether this is a public-access AED that they have retrieved themselves en-route or their own device, but it should not be technically difficult to make this small amendment to the data collection process.

#### **9.4.4 Step 4: Identify what needs to change**

In **Table 9.1** I have specifically considered what needs to change to increase retrieval of a public-access AED by GoodSAM responders during an alert, categorised by COM-B component. The decision that there is a potential need for change is based on findings from the interview study and my own judgement.

**Table 9.1: Improving retrieval of a public-access AED – what needs to change?**

<b>COM-B Component</b>	<b>What needs to happen for target behaviour to occur?</b>	<b>Is there a potential need for change?</b>
<b>Psychological capability</b>	GoodSAM responder is aware of public-access AEDs displayed on screen	<b>Yes:</b> Interview participants did not always remember seeing if nearby AEDs was displayed on screen at the time of an alert
	GoodSAM responder knows about the potential benefit of CPR/AED	<b>No:</b> Interview participants understood that early CPR/AED use could improve OHCA survival
	GoodSAM responder knows about the existence of public-access AEDs	<b>No:</b> Interview participants reported a good level of knowledge
<b>Physical opportunity</b>	There is a public-access AED close enough to both patient and GoodSAM responder	<b>No:</b> This is not something that can be affected by GoodSAM responders directly. Increasing numbers and optimising placement of public-access AEDs is beyond the scope of this project
	GoodSAM responder can access and retrieve a public-access AED	<b>Yes:</b> Interview participants expressed concerns about locating and negotiating for the release of public-access AEDs
<b>Reflective motivation</b>	GoodSAM responder is able to leave their current situation	<b>No:</b> The suitability of leaving professional or personal commitments is not a 'behaviour' for which we can make an intervention here. This will also (and perhaps primarily) affect the decision to respond in the first place.
	GoodSAM responder wants to retrieve a public-access AED en-route to the patient	<b>Yes:</b> There is no clear evidence about the correct strategy (direct to patient or via AED first) and no effective prediction tool for this. The decision has to be made on a case-by-case basis. Interview participants indicated that a lack of information about what was happening on scene was a barrier to deciding to retrieve an AED en-route to the patient
	GoodSAM responder must believe that they can retrieve a public-access AED and reach the patient before the ambulance service	<b>Yes:</b> some interview participants indicated they did not believe this was possible; there were concerns about locating and removing a public-access AED but also – in many cases – there was previous experience of responding promptly and not arriving before the ambulance service. This may also affect the decision to accept an alert in the first place
<b>Automatic Motivation</b>	GoodSAM responder must overcome anxiety or stress about accepting an alert or using a public-access AED	<b>Yes.</b> Some interview respondents indicated that they would welcome feedback or debrief. Even those with healthcare experience may be anxious about acting outside their usual scope of practice. Their experience of this may also affect the decision to accept an alert in the first place.

#### 9.4.5 **Step 5: Identify intervention functions**

Where I have identified a potential need for change I have identified one or more intervention functions to allow GoodSAM responders to deliver that change while responding to an alert.

**GoodSAM responder is aware of public-access AEDs displayed on screen (psychological capability)**

***Intervention function: Training.*** How to identify and locate AEDs, and/or how to use the app to do this.

There would be substantial cost, time and resource implication associated with formal training in this area and it is unlikely that GoodSAM could deliver this at present. The GoodSAM app already allows its users to take a photo of an AED and upload its position themselves to the app (174). GoodSAM have previously actively encouraged its users to do that, in order to build up a comprehensive registry of public-access AEDs. There is evidence from the interview study that some responders already use the app to locate public-access AEDs before an emergency.

*Investigate further? No.*

***Intervention function: Enablement (1).*** This would take the form of regular reminders via the app (not delivered at the time of an alert) that nearby public-access AEDs are always displayed in the app.

This is a technically feasible intervention that is likely to be low-cost. The key question is whether or not a reminder delivered in a non-emergency setting would change responders' behaviour during a time-critical situation when accepting an alert.

A review of 94 studies suggested that planning in advance about how one will perform a specific act or skill in a given situation or under given circumstances

– ‘implementation intention’, a more in-depth thought process than just setting an overall goal – has a moderate to large effect on the likelihood of performing that behaviour. There is heterogeneity in the form that such prompts take, their frequency and temporal relationship to the behaviour of interest (356), and so more information about how and when to deliver reminders in this setting is required. Regular prompts or reminders of these planned responses may enable the target behaviour to be enacted more quickly when it is required (357). We are responsive to who gives us the information (interview participants were generally positive about GoodSAM), and we often act in ways that make us feel better about ourselves (there was general positivity about the use of AEDs in OHCA) (358).

It could be available to all GoodSAM users via the app itself.

*Investigate further? Yes.*

***Intervention function: Enablement (2).*** Using the app to highlight the location and availability of the nearest AED at the time of an alert.

There would be substantial programming costs and resource implications to implement this, based on discussions with GoodSAM team and experience of other programming costs (for work in **chapter 10**). However, it is technically feasible.

Interview study findings suggested GoodSAM responders do not spontaneously consider retrieving an AED when alerted.

Content, style and the medium of messages all contribute to how the information that they contain is processed by the target audience (359). Effective and timely messaging can make people feel more in control of a situation, even in educated groups who are more aware of the consequences of ‘getting it wrong’ (360). A study of smartphone apps in the NHS Health Apps library using some form of gaming for health promotion reported that 31% used prompts and cues in their design (361). However, there is a gap in the literature

about the use of prompts and cues for mobile-phone apps activating volunteer first-responders in a time-critical situation.

Additional cues at the time of an alert, when a decision has to be made about accepting the alert and then about whether to retrieve a public-access AED could potentially add to GoodSAM responders' cognitive stress. Uncertainty about the best strategy may also contribute to feelings of a lack of control over the situation, increase or sustain high levels of anxiety and impair decision-making and/or performance (362). Strategies to mitigate the effect of this include ensuring that a GoodSAM responder only has to consider information directly related to the task at hand, delivering information in more than one format (e.g. visual and audio), and reducing the need to actively engage with the app to find the required information (e.g. information appears in pop-up windows automatically) (346).

*Investigate further? Yes.*

### **GoodSAM responder can access and retrieve a public-access AED (physical opportunity)**

Potential problems are:

- Gaining access to AEDs in locked cabinets. An unknown proportion of public-access AEDs require a code to gain access.
- Negotiating for the release of an AED from its custodian. There is no current evidence about the scale of this issue, but several interview participants raised this concern.

***Intervention function: Training.*** In this context, communications training for GoodSAM responders.

GoodSAM has more than 40,000 users worldwide (174) and providing effective communications training for all of them would not be feasible for GoodSAM to implement.

The effect of this intervention is uncertain and would be difficult to measure. There is no evidence about whether or not GoodSAM responders would be willing to engage with such training, or would feel it is necessary. Access to the intervention would be restricted by the availability of training.

*Investigate further? No.*

***Intervention function: Restriction.*** Not applicable here. There is no competing behaviour that one could appropriately restrict to increase AED use. GoodSAM responders must decide upon the correct strategy (retrieve a public-access AED first or go directly to the patient) case by case.

***Intervention function: Environmental Restructuring (1).*** Provision of 999 access codes on-screen during an alert, to help GoodSAM responders retrieve AEDs from locked cabinets.

There would be substantial programming costs and resource implications, and it relies on data being accurate and up-to-date. The GoodSAM app allows users to upload the location of public-access AEDs (by taking photos on a smartphone with location data enabled) and provide additional information such as the access code. GoodSAM can then verify this information from the local ambulance service or AED custodian.

The effectiveness of the intervention depends in part on the accuracy and completeness of information available to GoodSAM. Evidence, although not from the UK, suggests that many public-access AEDs are not known to ambulance services, even when registration with them is mandated by law (111). The British Heart Foundation (BHF) launched a national database in the UK in June 2019 (109), but there is no published evidence yet of its effect on capturing public-access AED locations.

It is logical that having a code would make it easier to retrieve an AED from a locked cabinet and increase willingness to attempt this, but there is no confirmatory evidence. It is a non-intrusive intervention that could be available to all app users at the time of the alert.

*Investigate further? Yes.*

***Intervention function: Environmental Restructuring (2).*** Improve the accessibility of AEDs by ensuring that they are in unlocked cabinets.

This is an intervention requiring input from multiple stakeholders, national-level changes and, possibly, legislative change. It is beyond the scope of GoodSAM to implement. There is no current evidence about the accessibility and speed of retrieval of public-access AEDs in locked vs unlocked cabinets, nor on the rates of theft or vandalism. One would have to explore the acceptability of this strategy to AED custodians and whether or not this would affect public-access AED provision in the first instance. It may also impact upon insurance cover and costs.

*Investigate further? No.*

***Intervention function: Enablement.*** Empower GoodSAM responders to successfully negotiate with an AED custodian for its release – for example, if it was located in a shop or a sports centre – by means of identification and a form of words presented via the app.

An 'identification' tab already exists on the app and could be modified so that a GoodSAM responder could explain their role and why they were asking for a public-access AED. Use of a template or fixed text would reduce programming costs and complexity further, and the GoodSAM responder would not need to reveal personal information. It would be readily available to all GoodSAM users.

This is an area that has not been specifically investigated before, although interview findings in this PhD do support the theory that GoodSAM responders would welcome an effective means of identifying themselves. Smartphone apps *do* exist to aid difficult communication for healthcare professionals (363), but there is no evidence specific to this field.

The use of prompts and cues is a recognised behavioural change technique (344). The exact language used in times of emergency affects how someone responds to you. Linguistic analysis of emergency calls for OHCAs shows that even small changes in word choice greatly affects the quality of information subsequently received from the person making the call (364). Anxiety may hinder effective communication (365) so, as discussed already, it is important not to add to cognitive load and to make communication prompts easy for the GoodSAM responder to access.

There is certainly a need for more research in this particular situation (persuading a stranger to release their AED to a remote location). Failure to return the AED to its custodian after the event is a potential concern, but it is logical that providing a mechanism for the return of the AED to its custodian (and reassurance that this would happen) would increase their willingness to release the AED to a remote location. This would, however, add complexity and cost to the intervention.

*Investigate further? Yes.*

### **GoodSAM responder wants to retrieve a public-access AED en-route to the patient (reflective motivation)**

There is no clear strategy or best practice regarding whether to divert for an AED first or to go directly to the patient. The decision remains with the GoodSAM responder, who must make this on a case-by-case basis.

***Intervention function: Education.*** Make GoodSAM responders aware that it may be appropriate to retrieve an AED in certain cases.

This information could be delivered via e-mail or the app, not at the time of an alert. It is a low-cost, technically undemanding intervention that is non-intrusive and would be available to all app users. It must be clear that retrieving a public-access AED is an option, but the decision remains that of the responder at the time of the alert.

We would need to study the effect and acceptability of providing information about an option when the outcome from taking that option is uncertain. Bystanders have previously indicated that if they were uncertain that the medical emergency was a genuine OHCA, they would be less likely to intervene (366). Bystanders at OHCA often report acting instinctively or with little reflection (268,366,367), but it is unclear whether or not this includes thinking about locating and retrieving a public-access AED. Preparation, and recognising that a real-life event is similar to training may help overcome these automatic impulses (367). Therefore, educational reminders that prompt people to make a pre-determined plan to consider AED use may improve the motivation to act.

When teaching resuscitation skills and emergency care knowledge, spaced learning rather than massed learning may increase knowledge retention at one year (368). The certainty of this evidence is very low and its applicability in this particular circumstance has not been tested.

*Investigate further? Yes.*

***Intervention function: Persuasion (1).*** Provide assurance that one can retrieve an AED with minimal delay in reaching the patient. This would require mapping and time estimates for both direct-to-patient and via-AED travel options.

Relevant information would be displayed in the app at the time of the alert, to allow the GoodSAM responder to make an informed decision about whether or not they could provide effective and timely assistance to a patient. In interviews, GoodSAM responders were concerned that an OHCA patient

might experience a harmful delay to CPR onset if they diverted to retrieve a public-access AED en-route. This uncertainty about benefits versus harms reduced their motivation to retrieve the AED.

Providing accurate information could reduce uncertainty and reduce anxiety levels (362), and create a more positive attitude towards AED retrieval (349). In a 2016 study of CPR intention in college students – considering aspects of the Theory of Planned Behaviour – attitude towards the behaviour was the strongest predictor of intention to perform CPR (369). As already discussed, there is a need to provide information in a precise and easily accessible manner to reduce additional cognitive load (346).

This would require substantial programming resource and cost, but would be available to all responders when receiving an alert. It would only potentially increase public-access AED retrieval in those alerts where the GoodSAM responder judges delay in routing via the AED is minimal. This depends in part on the number and positioning of public-access AEDs, which is not under GoodSAM's control. There is also no data on how often a public-access AED is positioned close enough to both responder and patient for its retrieval to be feasible, and capturing this data adds complexity to programming and future studies testing this intervention.

*Investigate further? Yes.*

***Intervention function: Persuasion (2).*** Specifically request (in-app at the time of alert) that one or more GoodSAM responders retrieves an AED first and one or more go directly to the patient. Inform those retrieving an AED that others are going directly to the scene.

This again would require substantial programming costs and resources, with modelling to determine which responder should go directly to the patient and which via an AED. Such an intervention requires there to be multiple responders to an alert, which work elsewhere in this PhD has shown happens rarely.

There would still be no means of ensuring that the GoodSAM responder tasked to go directly to the patient would actually reach the patient, and so there is still the potential for a delay to CPR initiation by diverting another responder via a public-access AED.

*Investigate further? Yes.* However, there is also ongoing research in this area in another, more mature, system in Denmark (183): a randomised controlled trial (RCT) comparing: all responders sent directly to patient vs some responders sent via an AED. It may be prudent to await the results of this RCT first.

***Intervention function: Incentivisation.*** Not applicable here. Incentives are not acceptable in this emergency situation where the best strategy (retrieval of AED first vs travelling directly to patient) isn't known, and where no model exists to predict the best decision in an individual case.

***Intervention function: Coercion.*** Not applicable here. It is not acceptable to mandate a course of action when the best strategy will vary from case to case.

**GoodSAM responder must believe that they can retrieve a public-access AED and reach the patient before the ambulance service (reflective motivation)**

***Intervention function: Education.*** Not applicable here. The decision is made based on real-time perceptions of how long it would take to retrieve an AED, and how long the ambulance response time is.

***Intervention function: Persuasion (1).*** Providing estimated time to patient via the nearest AED alongside estimated ambulance response times, enabling the GoodSAM responder to decide if they can retrieve an AED and get to the scene before the ambulance service.

This again would require substantial programming costs and resources, and will partly depend on the ease with which ambulance response times can be transferred from ambulance service systems to GoodSAM. If this information is inaccurate or if there are delays in interfacing and transferring information this could negatively impact upon patient care. There would have to be work with both parties first to determine whether this intervention was possible and acceptable to both parties.

Interview participants indicated frustration at arriving after the ambulance service and that this could reduce future motivation to accept alerts or to divert via a public-access AED alert first.

As mentioned above, although the decision to retrieve a public-access AED in any given situation remains that of the GoodSAM responder, providing the appropriate amount of information (346) and reducing uncertainty may improve attitudes towards the behaviour and influence the intention to carry it out (349,362,369).

*Investigate further? Yes.*

***Intervention function: Persuasion (2).*** Modify the app to update GoodSAM responders if the ambulance arrives on scene before them.

This issues here are similar to providing time estimates and would allow GoodSAM responders to call off their response if they knew they were not required any longer. It may be that providing time to patient/ambulance response time estimates and sending a 'stand-down' message if the ambulance arrives first are best delivered as one intervention.

Again, it relies on accurate information and a timely update from ambulance service to GoodSAM systems. In the interview study there were occasions when GoodSAM responders arrived after the ambulance service and were still permitted to provide assistance, so we would need to investigate whether or not this is an acceptable intervention to GoodSAM, its responders and the

ambulance services. Providing accurate and appropriate information, as above, may improve attitudes towards the behaviour in question (349,362,369) .

*Investigate further? Yes.*

***Intervention function: Incentivisation.*** Not applicable here, as previously discussed.

***Intervention function: Coercion.*** Not applicable here, as previously discussed.

### **Overcome anxiety or stress about accepting an alert or using a public-access AED (automatic motivation)**

There is an argument that many of the interventions already suggested will, if implemented effectively, contribute to a reduction in anxiety or stress about using a public-access AED or accepting an alert in the first place. In the interview study, only one respondent reported a reluctance to accept an alert because of anxiety and doubt in their own capability. However, as discussed in **chapter 8**, a potential selection bias may mean that anxiety and stress in the general GoodSAM responder population is higher than was captured in that study.

***Intervention function: Persuasion.*** Designing interventions to specifically persuade people who are anxious or stressed to accept an alert or retrieve a public-access AED may be unacceptable to responders, researchers or other stakeholders. Implementing other interventions that have already been discussed will be more appropriate.

*Investigate further? No.*

***Intervention function: Incentivisation.*** Not applicable here, as previously discussed.

**Intervention function: Coercion.** Not applicable here, as previously discussed.

**Intervention function: Training.** Provide training resources about dealing with stressful situations

It is likely to be more appropriate to use an existing, validated tool with a rigorous evidence-base rather than to develop a bespoke training resource for GoodSAM responders. It is not clear how many responders feel that this would be necessary, and how many of those would be prepared to use such a resource.

Behaviour is strongly linked to the intention or readiness to perform said behaviour, yet traditional resuscitation skills training – for the layperson at least – places very little focus on this (370). Anxiety and panic are seen in bystanders dealing with OHCA's (268). Providing training that prepares people for the possible psychological impact of intervening (or being asked to intervene) (367,371), and also discusses positive attitudes (369) and societal obligations (367) towards CPR and AED use may be worthy of investigation. This, however, is a wider training issue for the resuscitation community to consider, and probably outside of GoodSAM's remit.

*Investigate further? No.*

**Intervention function: Restriction.** Not applicable here, as previously discussed.

**Intervention function: Environmental Restructuring.** Not applicable here.

**Intervention function: Modelling.** Not applicable here.

**Intervention function: Enablement.** Provide a voluntary debrief to those who experience psychological distress following a GoodSAM activation.

This may be difficult and expensive to implement on a large scale for all responders, but researchers could investigate the impact and acceptability of a small-scale or local scheme. It would require substantial expertise and resource to provide helpful support to those who needed it, rather than exacerbating the problem. Sign-up would have to be voluntary (i.e. not persuaded or coerced) and it would be important to monitor short- and longer-term participant outcomes.

Adverse psychological effects in volunteer first-responders are not common (262,355). In Denmark, the 'Hearrunner' system provides the offer of formal debrief to all those who identified in a post-event questionnaire that they were suffering from severe psychological distress (355).

In a questionnaire delivered in Sweden to 544 bystanders who had participated in CPR (1992–1995), negative bystander psychological reactions were related to a lack of debrief and fatal victim outcome in multivariate logistic regression modelling (372). Similarly, in interviews with 20 bystanders in Norway (2013–2014) a fatal or uncertain patient outcome caused guilt and was difficult for bystanders to cope with. Most respondents had a desire for either some follow-up and/or an acknowledgement of their efforts from the statutory emergency services (373). Self-doubt because of a lack of information after the event were also reported in a group of 15 Canadian bystanders involved in OHCA's (2015–2016) (371). Positive short-term feelings may occur following bystander intervention, and in one study these persisted in bystanders for two months if they had received post-event debrief from members of the ambulance service (335).

*Investigate further? Yes.*

**9.4.6 Step 6: Identify policy categories; Step 7: Identify behaviour change techniques; Step 8: Identify mode of delivery**

In **Table 9.2**, I have identified potential interventions for the target behaviours, and presented the policy categories (step 6), behaviour change techniques identified from the BCTTv1 (344) (step 7), and modes of delivery (step 8) intended to support their successful delivery.

I have identified ten interventions worthy of further investigation: two targeting a GoodSAM responder's capability to perform this behaviour, two targeting opportunity and six targeting motivation. The intervention functions used were enablement (four times), persuasion (four), education (one) and environmental restructuring (one).

**Table 9.2: Potential interventions for behaviour change: retrieval of a public-access AED en-route to a patient**

What needs to change (behavioural determinants)	Potential intervention	Intervention function	Policy category	Potential behaviour change techniques	Mode of delivery
<p><b>PSYCHOLOGICAL CAPABILITY</b> Be aware of public-access AEDs displayed on screen</p>	Provide reminders about nearby AED locations	Enablement	Communication / marketing: provide regular reminders about AED locations Guidelines: introduce recommendations about checking for AED locations into GoodSAM code of conduct	Prompts / cues	Information via e-mail Visual/audio/voice prompt in-app <i>Delivered at regular, spaced intervals – <b>not</b> at the time of an alert</i>
<p><b>PSYCHOLOGICAL CAPABILITY</b> Be aware of public-access AEDs displayed on screen</p>	Highlight the location of the nearest AED at the time of the alert	Enablement	Environmental / Social planning: designing the in-app environment to enable people to recognise the location of the nearest AED	Prompts / cues	Visual/audio/voice prompt in-app <i>Delivered during an alert</i>
<p><b>PHYSICAL OPPORTUNITY</b> Be able to access and retrieve a public-access AED</p>	Provide access codes to AEDs in locked cabinets	Environmental Restructuring	Guidelines: Recommendations about how to access public-access AEDs Regulation: Voluntary agreement with ambulance services and other AED custodians to provide access codes Legislation: National-level laws to facilitate access to locked cabinets, e.g. mandated provision of access codes	Prompts / cues	Visual/audio/voice prompt in-app <i>Delivered during an alert, specific to relevant and local AEDs only</i>
<p><b>PHYSICAL OPPORTUNITY</b> Be able to access and retrieve a public-access AED</p>	Provide standardised information to show custodians of public-access AEDs	Enablement	Guidelines: provide a document to GoodSAM responders with recommended form of words Communication / marketing: information campaign targeting AED custodians	Information about health consequences Saliency of consequences Information about others' approval Use of credible source	Visual display in-app (to show custodian) Print media campaign Digital media campaign Printed card (to leave with custodian)

What needs to change (behavioural determinants)	Potential intervention	Intervention function	Policy category	Potential behaviour change techniques	Mode of delivery
<p><b>REFLECTIVE MOTIVATION</b> Want to retrieve a public-access AED en-route to patient</p>	Provide reminders that it may be appropriate to <i>consider</i> retrieving a public-access AED	Education	<p>Communication / marketing: reminders re: appropriate AED use Guidelines: recommendations about appropriate situations for AED use</p>	<p>Information about health consequences Information about social and environmental consequences Salience of consequences</p>	<p>Information via e-mail Information via app <i>Delivered at regular, spaced intervals – not at the time of an alert</i></p>
<p><b>REFLECTIVE MOTIVATION</b> Want to retrieve a public-access AED en-route to patient</p>	Provide route and distance/time estimates for direct-to-patient and via-nearest-AED travel option	Persuasion	<p>Communication / marketing: deliver 'real-time' information to GoodSAM responder via app Environmental / social planning: designing in-app environment to display AED and incident location</p>	Information about social and environmental consequences	Visual/audio/voice prompt in-app
<p><b>REFLECTIVE MOTIVATION</b> Want to retrieve a public-access AED en-route to patient</p>	Send some responders (if multiple responders available) to retrieve a public-access AED first	Persuasion	<p>Communication / marketing: sharing information about each responders' actions (so all involved know that someone is retrieving AED and someone is going to scene) Guidelines: explaining why GoodSAM responder should retrieve AED first if asked Regulation: rules on when GoodSAM responder(s) should retrieve AED first</p>	Information about social and environmental consequences	<p>Visual/audio/voice prompt in-app <i>Delivered during an alert</i> Website Code of Conduct E-mail updates <i>Spaced intervals – not at the time of an alert</i></p>

<b>What needs to change (behavioural determinants)</b>	<b>Potential intervention</b>	<b>Intervention function</b>	<b>Policy category</b>	<b>Potential behaviour change techniques</b>	<b>Mode of delivery</b>
<p><b>REFLECTIVE MOTIVATION</b> Believe that one can retrieve a public-access AED and reach patient before the ambulance service</p>	Provide time-to-patient and ambulance response-time estimates at the time of an alert	Persuasion	Communication / marketing: deliver 'real-time' information to GoodSAM responder via app Regulation: organisational rules about safely transferring information from ambulance services to GoodSAM	Information about social and environmental consequences Salience of consequences Use of credible source	Visual/audio/voice prompt in-app <i>Delivered during an alert</i>
<p><b>REFLECTIVE MOTIVATION</b> Believe that one can retrieve a public-access AED and reach patient before the ambulance service</p>	Update GoodSAM responder if ambulance arrives on scene	Persuasion	Communication / marketing: deliver motivational information directly to responder at time of alert	Persuasion about capability	Visual/audio/voice prompt in-app <i>Delivered during an alert</i>
<p><b>AUTOMATIC MOTIVATION</b> Overcome anxiety or stress about accepting an alert or using a public-access AED</p>	Offer voluntary debrief after an alert	Enablement	Service provision: survey GoodSAM responders, identify those at risk of psychological harm, and offer appropriate follow-up for those who need it	Social support (emotional) Review behaviour goals Review outcome goals	In-app survey post-alert Face-to-face / telephone follow-up if needed

## 9.5 DISCUSSION

### 9.5.1 Main findings

The problem that I investigated was the low rate of public-access AED use by GoodSAM responders during an alert, and I identified a number of steps required for successful public-access AED use. I investigated the potential for behavioural change for a GoodSAM responder deciding (or not) to retrieve a public-access AED en-route to the patient, which I subsequently judged an acceptable behaviour to target for potential behavioural change. I identified ten possible interventions to achieve this: two increasing capability to retrieve a public-access AED, two increasing opportunity and six increasing motivation. The intervention functions used were enablement (two capability; one opportunity; one motivation), environmental restructuring (one opportunity), education (one motivation), and persuasion (four motivation).

### 9.5.2 Comparison with the literature

The TDF, COM-B and the BCW have been used together to deliver previous interventions in healthcare delivery ([198,374](#)), or to describe proposed interventions ([375](#)). This chapter represents the first time that anyone has used recognised behavioural frameworks to develop potential interventions to improve public-access AED use in a volunteer first-responder system. Much of the literature related to barriers to public-access AED use relates to bystanders (rather than volunteer first-responders) and is based on observational data and unvalidated surveys or questionnaires ([111](#)) and **chapter 4**).

There are a few studies that have explored barriers and facilitators to CPR or AED – albeit in bystanders rather than in volunteer first-responders – using more rigorous qualitative approaches.

Researchers in Denmark conducted 26 semi-structured interviews with CPR-trained (but non-healthcare-provider) bystanders attending consecutive

OHCA where there was already an AED present. They performed a thematic analysis and identified that hands-on CPR and AED training, and prior knowledge that CPR and AED use affects outcomes facilitated CPR and AED use. A perceived moral obligation to respond, and teamwork with other bystanders at the scene were also motivating factors (268).

In Tasmania, researchers asked 15 people that signed up to a scheme alerting local AED custodians to nearby OHCA to participate in semi-structured interviews, investigating 'human factors' that might facilitate an OHCA response. Of the 12 that participated, all responded to the OHCA when asked, and their previous experience and perceived competency in managing OHCA were the strongest motivators (376). This very select group, of people anticipating responding to an OHCA when asked, may be more similar in nature to GoodSAM responders than to bystanders.

There are similarities in both of these studies' findings with the interview study (chapter 8), notably the effect of training, experience and knowledge on the likelihood to perform a behaviour (i.e. respond, or perform CPR +/- use an AED). However, what neither of these studies did is use theoretically-informed approaches to develop these findings into an articulate set of interventions that could be tested to improve the response to OHCA. In this way, I believe the current study stands apart.

### **9.5.3 Strengths and limitations**

In this chapter I have taken a systematic approach to intervention development using empirical evidence from my interview study and the published literature, and recognised behavioural frameworks. The BCW was developed by expert consensus and a review of 19 existing frameworks for behaviour change, and was designed to be more comprehensive than those that came before. It integrates with the TDF and COM-B to allow a logical transition from data acquisition and coding right the way through to producing a list of potential interventions. I can also use it in the future to design and evaluate trials of these interventions (199).

However, there is currently a lack of rigorous evidence about the effectiveness of behavioural change techniques, both in isolation or in combination, to change behaviour (377). There is no data on the successful application of the BCW and/or other recognised behavioural change theories to the population of volunteer first-responders for OHCA. Reviewing the literature in more depth and identifying relevant theories to apply to each proposed intervention will be a vital starting point for the intervention development process (203,204).

I developed interventions based on interview responses from GoodSAM responders, but interviews with 30 respondents do not allow for measurement of the scale or frequency at which these issues occur across the whole GoodSAM responder system. Developing and validating a survey based on TDF domains could potentially address this issue (378,379). Further, if participants were not representative of GoodSAM responders as a whole (discussed in **section 8.5.3**) I may have failed to identify other effective targets for behaviour change during the interviews. The interventions that I have presented here might not all be optimally targeted at the typical GoodSAM responder.

It may not be appropriate to target change of the key behaviour in GoodSAM responders alone. For example, I considered that negotiating for the retrieval of an AED was an ‘opportunity’ barrier for the GoodSAM responder, but one might reasonably consider the motivations of the AED custodian. Deciding to retrieve an AED is also contingent upon deciding to accept an alert. The successful outcome of AED attachment once the AED has been retrieved may also depend on a GoodSAM responder’s knowledge and skills in AED use.

I employed substantial individual judgement in developing these interventions. In truth, preparing an intervention for testing in a research study will be an iterative process involving multiple stakeholders, including: GoodSAM and local ambulance service employees (e.g. can we technically do this, do we consider it appropriate after risk-assessment procedures?), GoodSAM responders (how do we ensure study compliance?), AED custodians (will they release public-access AEDs?), OHCA survivors (how do they feel about

potential rescuers taking a particular action?), and other resuscitation experts (what is the risk/trade-off between earlier CPR and earlier AED and how is this mitigated?).

#### **9.5.4 Clinical implications**

Successful AED use by a GoodSAM responder requires several things to happen. The decision about how many behaviours to try and change is a difficult one – it may be better to focus on a small number of behaviours (199). In this case, deciding whether or not to retrieve a public-access AED is the key behaviour, but it can only occur once a GoodSAM responder has decided to accept an alert. Clearly it is important not to consider these two related decisions in isolation. A review of systematic reviews suggests that multiple, linked interventions are often more effective than those with only one component (202).

GoodSAM responders are a select group, with prior CPR training, and in the interview study (**chapter 8**) they generally seemed motivated to provide meaningful assistance to OHCA patients. Despite this, we still might not be able to change key behaviours and bring about meaningful change if the intervention is poorly designed. Following implementation of an intervention, there must be the means to evaluate and revise interventions when needed. The implementation, rather than the intervention itself, may be flawed, particularly in complex systems involving complicated interactions between people and their environment (203).

The Medical Research Council provides guidelines about how to design appropriate trials to evaluate different interventions (203), and the National Institute for Health and Clinical Excellence (NICE) has provided guidance on developing and evaluating interventions to enable behavioural change at a local level (380). In this PhD, I have only provided a starting point to test interventions in GoodSAM and, hopefully, in similar volunteer first-responder systems worldwide.

### 9.5.5 Next steps

I have already shared key findings from this chapter with representatives of GoodSAM and London Ambulance Service, and by means of peer-reviewed publication (189). London Ambulance Service have shared the results with local patient groups. The research team I am part of will consider, along with key stakeholders, how to begin the process of designing studies to evaluate these behaviour change interventions. This will include a robust research priority-setting exercise. We shall follow guidance from the Cochrane Priority Setting Methods Group, who have identified a number of tools that can assist with this process (381).

Other researchers may also use the processes described in both **chapters 8 and 9** to identify and overcome barriers to public-access AED use – or, indeed, some other aspect of the volunteer first-response – that are specific to their own systems.

## 9.6 CONCLUSION

Retrieving a public-access AED en-route to an OHCA is an important and suitable target for behavioural change in order to increase public-access AED use by GoodSAM responders during an alert. I have demonstrated that it is possible to use the BCW to develop a list of interventions for future investigation. Researchers in similar app-based volunteer first-responder systems could employ similar theoretically-informed methods to improve AED use in their own systems.

# CHAPTER 10

Determining the optimum activation  
distance for GoodSAM first-  
responders alerted to a nearby out-of-  
hospital cardiac arrest

---

The maps displayed in this chapter are either 'OS Vector Map District' (for small- and mid-scales) or 'OS Open Map Local' (for larger scales). The ArcGIS programme in which the maps were generated automatically changes the basemap based on the scale.

Both of these maps are available under the 'Open Data' licence from Ordnance Survey, which are covered by the Open Government Licence (OGL) <http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/>. This allows for copying and distribution of the data, with the following attribution statement:

**Contains OS data © Crown copyright and database right (2019)**

---

## **10.1 INTRODUCTION**

In 2018, 9.3% of people sustaining an out-of-hospital cardiac arrest (OHCA) in England survived to hospital discharge ([12](#)). Bystander cardiopulmonary resuscitation (CPR) ([6](#)) and bystander public-access Automated External Defibrillator (AED) use ([69,122](#)) improve survival to hospital discharge. Volunteer first-responders alerted by mobile phone have provided both CPR ([162,164](#)) and defibrillation ([164](#)). However, there is a lack of high-quality evidence about the effect of these systems on clinical outcomes ([159](#)).

In the UK, the GoodSAM mobile-phone app integrates with several local ambulance services. During an emergency (999) call GoodSAM alerts trained volunteer first-responders about a nearby OHCA. In **chapter 6** I reported that acceptance of an alert by a GoodSAM responder was associated with improved survival to hospital discharge in both London and East Midlands. However, very few GoodSAM responders accepted an alert. On the basis on these findings GoodSAM increased the response radius in London from 300m to 400m for Tier 3 responders and to 700m for Tier 1 and Tier 2 responders.

There are a number of unanswered questions regarding the effect of GoodSAM responders on OHCA outcomes. I could not determine with the data available for **chapter 6** whether or not responders accepting an alert reached the patient, or what interventions they performed on scene. At the

time of the work in **chapter 6**, indicating arrival on scene required a responder to press a button in the app, and it is unlikely that all responders would have done that. Post-event incident reporting was not always completed. By the time of the work in this chapter, GoodSAM determined arrival on scene when the Global Positioning System (GPS) location of the responder's phone indicated that they had arrived at the incident location.

GoodSAM responders in London also indicated in interviews (**chapter 8**) that they – often on numerous occasions – would arrive at the scene only after the ambulance service had arrived. Accurately recording which responders arrived on scene before the ambulance service, and the distance that they travelled to attend the scene may give a clearer indication about the optimum activation distance. If the activation distance is too small, then the potential for responders to arrive first and render assistance is smaller. If the activation distance is too long, responders who arrive after the ambulance service may become less motivated to respond to future alerts.

## **10.2 AIM AND OBJECTIVES**

The aim in this chapter was to determine the optimum activation distance for GoodSAM first-responders alerted to a nearby OHCA in London and East Midlands.

The objectives were to:

- Determine the proportion of GoodSAM alerts resulting in a responder reaching the patient's side before the arrival of the ambulance service
- Determine the optimum threshold for GoodSAM responder travel distance, when considering whether or not they reached the patient's side before the ambulance service
- Examine the effect in London on increasing the response radius from 300m to 400m (Tier 3 responders) and 700m (Tier 1 and 2 responders)

- Determine whether or not a GoodSAM responder reaching the patient's side was independently associated with survival to hospital discharge in OHCA cases

## **10.3 METHODS**

### **10.3.1 System description**

In **chapter 6 (section 6.3.1)** I have described the population served by London Ambulance Service (LAS) and East Midlands Ambulance Service (EMAS), and the use of GoodSAM following diagnosis of potential OHCA during a 999 call. I have described the criteria that each ambulance service used to activate GoodSAM in **chapter 5 (Table 5.1)**. LAS currently activate up to three GoodSAM responders within a 400m (for Tier 3 responders) or 700m (for Tier 1 and 2 responders) radius of a potential OHCA. EMAS activate up to five responders within an 800m radius.

### **10.3.2 Data sources**

#### *Out-of-Hospital Cardiac Arrest Outcomes registry*

I signed a data-sharing arrangement with the Out-of-Hospital Cardiac Arrest Outcomes (OHCAO) registry on 25<sup>th</sup> June 2019 for access to six months data (September 2019 – March 2020) about confirmed OHCA cases submitted to them by LAS and EMAS. Disruptions due to the COVID-19 pandemic meant that only data to the end of December 2019 were ultimately available.

#### *GoodSAM*

The University of Warwick (on my behalf) signed a data-sharing arrangement with GoodSAM on 16<sup>th</sup> July 2019 for access to six months' data (September 2019 – March 2020).

Collecting and collating data on GoodSAM responder position at the time of an alert required additional programming work. To this end, GoodSAM and the University of Warwick agreed a subcontract for this work on 2<sup>nd</sup> September 2019. The costs were covered as part of my National Institute for Health Research (NIHR) Doctoral Research Fellowship.

### **10.3.3 Data collection**

I collected the following information from the OHCAO registry (both ambulance services unless indicated):

- Patient age (years)
- Patient gender
- Date of 999 call
- Time of 999 call
- Time ambulance vehicle stops
- Location of OHCA (as postcode: for all OHCA in LAS, for residential OHCA only in EMAS)
- OHCA witnessed by (EMS\*/bystander/unwitnessed)
- Bystander CPR performed
- Public-access AED used by public (LAS only)
- Initial cardiac arrest rhythm (ventricular fibrillation/ventricular tachycardia (VF/VT), pulseless electrical activity (PEA), asystole)
- Return of spontaneous circulation (ROSC) at hospital
- Survival to hospital discharge

(\*EMS = *Emergency Medical Services* or 'ambulance service' in the UK)

I calculated an ambulance service (EMS) response time as the difference between 'Time ambulance vehicle stops' and 'Time of 999 call'.

GoodSAM provided the following information about every 999 call ('incident') for which a GoodSAM alert was sent (regardless of whether a GoodSAM responder accepted the alert or not):

- Date and time of GoodSAM alert
- Number of GoodSAM alerts accepted, not seen and rejected
- Time that responder arrived on scene (if applicable)
- Location of incident (as latitude/longitude)
- Location of GoodSAM responder at time of incident

Additionally, following a GoodSAM alert there is the opportunity for GoodSAM responders to complete post-event feedback via the app – for this GoodSAM provided the following data: nature of emergency, was CPR provided or an AED used, and a free text section for additional information. The 'nature of emergency' data field had a number of drop-down options (including cardiac arrest, difficulty breathing, drug/alcohol/overdose, hypoglycaemic episode, seizure, stroke) and also allowed for free-text entry.

I devised a questionnaire to help determine whether or not a GoodSAM responder accepting an alert arrived at scene before the ambulance service:

- *Did you get to scene?* Yes/No
- *How did you get to the scene?* Motor vehicle/Foot/Bicycle/Not applicable (did not get to scene)
- *Did you get to the patient?* Yes – before the ambulance/Yes – after the ambulance/No/I was on-duty with the ambulance service
- *Was the patient in cardiac arrest?* Yes/No/Not applicable (did not get to patient)
- *What assistance did you provide?* CPR/Defibrillation/Other/Not applicable (did not get to patient)

It was not feasible to integrate this questionnaire into the post-event reporting in-app, so GoodSAM invited responders to complete the questionnaire via Survey Monkey (SVMK Inc., California, USA) following an alert. GoodSAM themselves matched the Survey Monkey responses with the rest of the information about each alert. They provided me with data in a single spreadsheet, with a separate row for each alert and its matching questionnaire response, if completed.

An error in compiling the questionnaire meant that only one answer was possible for “what assistance did you provide?”, so it was not possible for a GoodSAM responder to indicate if they had provided more than one intervention (e.g. CPR *and* defibrillation).

I matched confirmed OHCA to a GoodSAM alert(s) – if one was made – by comparing OHCA location and date/time information from both data sources. For the EMAS data I was only able to do this for residential OHCA, as detailed address information for non-residential incidents (apart from an Utstein definition (9) e.g. ‘public’ or ‘work’) was not provided. Thus, data presented here about confirmed OHCA in East Midlands are confined to residential OHCA only.

#### **10.3.4 Data storage**

Both GoodSAM and the OHCAO registry provided information in a Microsoft Excel (Microsoft Corporation, Washington, USA) spreadsheet, and I also used Excel when matching OHCA cases to GoodSAM alerts and when combining data. I accessed data either on a desktop computer in Warwick Clinical Trials Unit (CTU) or on a University-managed laptop. Both used Windows 10 and data files were a) password protected and b) encrypted.

#### **10.3.5 Data analysis and reporting**

Data on all GoodSAM alerts were available 20<sup>th</sup> September 2019 – 22<sup>nd</sup> March 2020 for LAS and 20<sup>th</sup> September 2019 – 17<sup>th</sup> March 2020 for EMAS. Data

about confirmed OHCAs from both ambulance services were available 22<sup>nd</sup> September – December 31<sup>st</sup> 2019.

From the data provided, I calculated the following: whether an incident occurred during the day or night, or on a weekday or weekend; EMS response time (the difference between the time of the emergency call and the EMS stop time); which London borough (LAS) or County or Unitary Authority (EMAS) an incident occurred in.

I defined 'day' as 0800-1959 and 'night' as 2000-0759. Christmas Day and Boxing Day were the only public holidays during this time and I classified them as 'weekend'.

I calculated the distance between an incident and a GoodSAM responder at the time of an alert using ArcGIS (version 10.5.1, ESRI, California, USA). I used 'OS Open Carto' (Ordnance Survey Limited, Southampton, UK) as the basemap and mapped the incident- and GoodSAM responder locations onto this. I first converted locations to Eastings/Northings using the UK Grid Reference Finder Batch Convert Tool (<https://gridreferencefinder.com/batchConvert/batchConvert.php>) so that the locations now matched the coordinate system of the basemap. I have described this process in more detail in **section 7.3.2**.

I used the 'XY to line' feature in ArcGIS to match each GoodSAM responder position to its relevant incident and provide a straight-line distance between the two points. To calculate the likely 'real-world' travel distance between GoodSAM responder and the incident I overlaid 'OS Open Local' Vector maps (<https://www.ordnancesurvey.co.uk/opendatadownload/products.html>) for the relevant areas of the UK onto the basemap. ArcGIS created a network along which I could plot an estimated travel route using roads and paths. Using the 'Network Analyst' tool in ArcGIS I matched GoodSAM responder locations to the relevant incident location using a common numerical identifier, and ArcGIS then 'solved' the travel route between them. I further calculated an estimated travel time to the incident (using a speed of 100m/min, after Deakin et al (276))

based on the real-world travel distance estimate. I have described the use of the Network Analyst tool in more detail in **section 7.3.3**.

Where I have presented visual mapping data in the results I have done so at a scale and level of detail that precludes identification of an individual location.

I obtained shapefiles (a mapping document format that can be overlaid onto a basemap) for London Boroughs from the London Datastore website (<https://data.london.gov.uk/dataset/statistical-gis-boundary-files-london>), and for East Midlands County and Unitary Authorities (December 2017, the most recent available) from the Office for National Statistics Open Geography Portal ([https://geoportal.statistics.gov.uk/datasets/6638c31a8e9842f98a037748f72258ed\\_0](https://geoportal.statistics.gov.uk/datasets/6638c31a8e9842f98a037748f72258ed_0)). I then matched incident location (map 'points') to the borough, county or unitary authority (map 'areas') within which they occurred using the 'Spatial Join' feature of ArcGIS.

There were instances when there was contradictory information from GoodSAM about the same incident. I have reported on this in the results. This happened in two circumstances:

1. Responses from the post-event in-app feedback and/or the Survey Monkey questionnaire contradicted the alert 'status' (whether a GoodSAM responder accepted, rejected or did not see the alert): e.g. the responder did not see or respond to the alert ('not seen') – accepting or rejecting an alert requires a button press on the mobile device – but they clearly described travelling to scene and providing assistance. Where there was a clear contradiction, I corrected the alert status manually (in this example from 'not seen' to 'accepted')
2. Responses from the post-event in-app feedback and/or the Survey Monkey questionnaire did not match: e.g. one source indicated CPR was performed and the other did not. In these cases all fields were reviewed to determine which information was correct. Where it was not possible to decide, precedence was given to the in-app feedback as I

determined (after discussion with GoodSAM) that it was more likely that this would have been completed contemporaneously. The in-app feedback mechanism is triggered following the end of an alert and GoodSAM sent out Survey Monkey invitations via e-mail in batches within a maximum of three days following the alert.

### *Statistical Analysis*

I have presented and collected data according to the Utstein guidelines (9), as previously described in **section 6.3.4**. I used SPSS Statistics (version 26, IBM, New York, USA) for all statistical analyses. I used the Shapiro-Wilk test to assess for normality of distribution for the continuous variables.

I have presented data about the proportion of GoodSAM alerts resulting in a responder reaching the patient (and other responder actions) as number and percentage. I compared alert acceptance and reaching the patient's side for day/night and for weekday/weekend, presenting unadjusted odds ratios (OR) with 95% confidence intervals (95% CI). For London data I have presented the number of alerts that would have been sent and the number and proportion that would have been accepted, had the response radius still been 300m and compared this to the actual figures in the study period (when the alerting radius was up to 400m/700m).

I have presented travel distance and speed as medians with interquartile range (IQR).

I created Receiver Operating Characteristic (ROC) curves and have presented Area Under the Curve (AUC) statistics to determine if there is an optimum activation threshold for GoodSAM alerts in London and East Midlands for a) alert acceptance and b) arrival at the patient before the ambulance service. If one could be determined the exercise would be repeated for individual boroughs, counties or unitary authorities to determine if the threshold differed between these regions. For each responder's distance from the incident, the ROC determines the likelihood of a 'true positive' (presented as the sensitivity:

in this case either alert acceptance or arrival at the scene before the ambulance) or a false positive (presented as 1-specificity: here, rejecting an alert or failing to reach scene that are correctly predicted). An AUC close to 1 suggests that responder distance is a good predictor of the outcome of interest; an AUC close to zero suggests distance gets the prediction wrong in most cases; and an AUC close to 0.5 suggests that whether or not the outcome occurs at a given responder distance is largely due to chance.

For confirmed OHCA cases only I created a logistic regression model for LAS and EMAS (separately). In these models, the variable of interest was a) accepting (or not) a GoodSAM alert ('model 1') or b) arrival (or not) at the patient's side before the ambulance arrived ('model 2'). The outcome variable was survival to hospital discharge (yes/no).

I included the following variables in the logistic regression models: GoodSAM group (model 1: accepted/not seen or rejected/no alert; model 2: at patient before ambulance/all other 'accepted'/not seen or rejected/no alert), age (years), gender (male/female), OHCA witnessed status (by ambulance service/by bystander/unwitnessed, LAS only), CPR performed (by ambulance service/by bystander/not performed, LAS only), bystander AED use (yes/no, LAS only), location type (residential/non-residential, LAS only), time of day (day/night), time of week (weekday/weekend), initial cardiac arrest rhythm (VF or VT/pulseless electrical activity (PEA)/asystole), ambulance service response time (seconds). I entered all variables into the model for their potential to impact the outcome in OHCA. There was no statistical procedure to determine entry into the model.

I did not include OHCA witnessed status and bystander CPR in the EMAS models. For this dataset, EMAS had recorded all non-bystander-witnessed OHCA as unwitnessed, and I was not able to determine which of these were EMS-witnessed rather than truly unwitnessed. These would automatically be classified as bystander CPR 'no' despite them having prompt EMS CPR very soon after the OHCA.

I have presented unadjusted odds ratios (OR) and adjusted odds ratios (AOR) with 95% confidence intervals (95% CI). I performed multicollinearity testing to determine to what degree the independent variables in the models correlated with each other. I have presented Cox and Snell  $R^2$  and Nagelkerke  $R^2$  values to indicate how much the predictor variables in the logistic regression model explain the outcome of interest. I have described these tests in more detail in **section 6.3.4.**

### **10.3.6 Ethical approvals**

The study received ethical approval from the Biomedical Sciences Research Ethics Committee (BSREC) at the University of Warwick on 5<sup>th</sup> June 2019 (reference: BSREC 50/18-19).

## **10.4 RESULTS**

### **10.4.1 London – all GoodSAM alerts**

There were 9453 GoodSAM alerts reported for 4870 incidents (20<sup>th</sup> September 2019 – 22<sup>nd</sup> March 2020). After excluding 2.9% (273/9453) alerts that were sent to an LAS employee already attending that incident whilst on-duty, there were 9180 alerts for 4776 incidents.

61% (5568/9180) alerts were sent during the day, and 70% (6401/9180) on a weekday (representing 71% or 5/7<sup>th</sup> of the week). Overall, GoodSAM responders accepted 23% of the alerts (2088/9180); 27% (2442/9180) were rejected and 51% (4650/9180) were not seen. There was some statistical evidence that GoodSAM responders were more likely to accept an alert during the day than at night (unadjusted odds ratio (OR) 1.14, 95% confidence interval 1.02-1.25;  $p=0.01$ ), but no evidence that responders were more or less likely to accept an alert on a weekday compared to a weekend (OR 0.96, 95% CI 0.86-1.07;  $p=0.45$ ). There was some statistical evidence that multiple acceptances were more likely during the day than at night (OR 1.28, 95% CI 1.01-1.63;  $p=0.04$ ) but no evidence that multiple acceptances differed

between a weekday and the weekend (OR 1.04, 95% CI 0.80-1.34; p=0.76).

**Table 10.1** details this further.

**Table 10.1: GoodSAM alert outcome (London)**

	Alerts	Multiple Accepted	Accepted	Rejected	Not seen
<b>Total</b>	<b>9180</b>	<b>302 (3.3%)</b>	<b>2088 (22.7%)</b>	<b>2442 (26.6%)</b>	<b>4650 (50.7%)</b>
Day	5568 (60.6%)	200 (3.6%)	1316 (23.6%)	1596 (28.7%)	2656 (47.7%)
Night	3612 (39.3%)	102 (2.8%)	772 (21.4%)	846 (23.4%)	1994 (55.2%)
Weekday	6401 (69.7%)	213 (3.3%)	1442 (22.5%)	1748 (27.3%)	3211 (50.2%)
Weekend	2779 (30.3%)	89 (3.2%)	646 (23.2%)	694 (25.0%)	1439 (51.8%)

More than one GoodSAM responder accepted an alert on 3.3% (302/9180) occasions: two people accepted, n=236; three, n=52; four, n=11; five, n=3.

I was able to map 99% (9068/9180) alerts to one of the 33 London Boroughs. I was able to map all of the remaining 122 alerts but these occurred on the periphery of the LAS region and did not correspond with a London Borough. The number of alerts in each borough ranged from 66 to 1218. The range of alerts accepted was 15-43%, rejected 14-32% and not seen 39-58%. The range of multiple alert acceptances was 0-8.7%. **Table 10.2** details this further.

**Table 10.2: GoodSAM alert outcome by London Borough**

	Alerts	Multiple Accepted	Accepted	Rejected	Not seen
<b>Total</b>	<b>9068</b>	<b>300 (3.3%)</b>	<b>2042 (22.5%)</b>	<b>2412 (26.6%)</b>	<b>4614 (50.9%)</b>
Barking & Dagenham	66	1 (1.5%)	28 (42.4%)	11 (16.7%)	27 (40.9%)
Barnet	299	17 (5.7%)	109 (36.5%)	42 (14.0%)	148 (49.5%)
Bexley	91	1 (1.1%)	26 (28.6%)	24 (26.4%)	41 (45.0%)
Brent	186	1 (0.5%)	37 (19.9%)	50 (26.9%)	99 (53.2%)
Bromley	156	3 (1.9%)	33 (21.1%)	48 (30.8%)	75 (48.1%)
Camden	754	30 (4.0%)	157 (20.8%)	193 (25.6%)	404 (53.6%)
City of London	182	8 (4.4%)	37 (20.3%)	55 (30.2%)	90 (49.5%)
Croydon	268	3 (1.1%)	55 (20.5%)	73 (27.2%)	140 (52.2%)
Ealing	152	5 (3.3%)	37 (24.3%)	34 (22.4%)	81 (53.3%)
Enfield	146	3 (2.1%)	30 (20.5%)	35 (24.0%)	81 (55.5%)
Greenwich	143	6 (4.2%)	45 (31.5%)	28 (19.6%)	70 (48.9%)
Hackney	257	7 (2.7%)	59 (23.0%)	70 (27.2%)	128 (49.8%)
Hammersmith & Fulham	262	6 (2.3%)	46 (17.5%)	83 (31.7%)	133 (50.8%)
Haringey	191	9 (4.7%)	57 (29.8%)	50 (26.2%)	84 (44.0%)
Harrow	130	5 (3.8%)	37 (28.5%)	35 (26.9%)	58 (44.6%)
Havering	122	1 (0.8%)	25 (20.5%)	34 (27.9%)	63 (51.6%)
Hillingdon	183	7 (3.8%)	67 (36.6%)	40 (21.9%)	76 (41.5%)
Hounslow	97	0 (0%)	22 (22.7%)	23 (23.7%)	52 (53.6%)
Islington	359	8 (2.2%)	58 (16.2%)	92 (25.6%)	209 (58.2%)
Kensington & Chelsea	207	7 (3.4%)	34 (16.4%)	55 (26.6%)	118 (57.0%)
Kingston upon Thames	150	13 (8.7%)	57 (38.0%)	34 (22.7%)	59 (39.3%)
Lambeth	577	15 (2.6%)	85 (14.7%)	170 (29.5%)	322 (55.8%)
Lewisham	209	5 (2.4%)	51 (24.4%)	65 (31.1%)	93 (44.5%)
Merton	179	4 (2.2%)	32 (17.9%)	46 (25.7%)	101 (56.4%)
Newham	247	8 (3.2%)	69 (27.9%)	71 (28.8%)	107 (43.3%)
Redbridge	109	2 (1.8%)	33 (30.3%)	28 (25.7%)	48 (44.0%)
Richmond upon Thames	105	3 (2.9%)	28 (26.7%)	27 (25.7%)	50 (47.6%)
Southwark	596	16 (2.7%)	100 (16.8%)	183 (30.7%)	313 (52.5%)
Sutton	145	3 (2.1%)	47 (32.4%)	39 (26.9%)	59 (40.7%)
Tower Hamlets	684	43 (6.3%)	177 (25.9%)	180 (26.3%)	327 (47.8%)
Waltham Forest	173	2 (1.2%)	35 (20.2%)	54 (31.2%)	84 (48.6%)
Wandsworth	425	17 (4.0%)	103 (24.2%)	106 (25.0%)	216 (50.8%)
Westminster	1218	41 (3.4%)	226 (18.6%)	334 (27.4%)	658 (54.0%)

### *GoodSAM responder actions*

GoodSAM responders who accepted an alert (n=2088) completed the post-alert Survey Monkey questionnaire on 76% (1589/2088) occasions. I was able to determine on-scene status from in-app records on a further 299 occasions – for a total of 90% (1888/2088) of accepted alerts.

In total, 86% (1800/2088) GoodSAM responders accepting an alert reported reaching the scene – or 95% (1800/1888) of those where the information was known. There were 69% (1450/2088) – or (77%) (1450/1888) – who reached the patient: 734 (35% or 39%) before the ambulance service, 609 (29% or 32%) after, with before/after status unknown in 107 (5.1% or 5.7%). The majority of responders travelled to scene on foot (51%, 955/1888), but a substantial proportion did so in a motorised vehicle (468/1888, 25%). GoodSAM responders indicated that the patient was in OHCA on 39% (745/1888) occasions. In these 745 reported OHCA, a responder reached the patient's side on 731 occasions: they provided CPR +/- defibrillation on 67% (258/385) occasions when they reached the patient before the ambulance service, 39% (111/285) when they reached the patient after the ambulance and 74% (45/61) when their arrival time at the patient's side was unknown. **Table 10.3** describes responses from the post-event questionnaire further.

**Table 10.4** further stratifies actions after alert acceptance by day/night and by weekday/weekend. There was no statistical evidence that GoodSAM responders were more or less likely to reach the scene in the day compared to the night (OR 0.86, 95% CI 0.55-1.34; p=0.5), or on a weekday compared to the weekend (OR 0.69, 95% CI 0.42-1.13; p=0.14).

Similarly there was no statistical evidence (in all cases, calculated from cases where arrival status data was known) of a difference in day versus night for arriving before the ambulance (OR 0.85, 95% CI 0.70-1.03; p=0.09) or providing CPR/AED for OHCA cases (OR 0.93, 95% CI 0.69-1.26; p=0.64); and no difference in weekday versus weekend for arriving before the

ambulance (OR 0.95, 95% CI 0.77-1.16; p=0.62) or providing CPR/AED for OHCA cases (OR 1.09, 95% CI 0.80-1.50; p=0.58).

**Table 10.3: Actions after alert acceptance (London)**

	<b>Number (%)</b>	
<b>On-scene information known</b>	<b>1888</b>	
<b>Reached scene</b>		
Yes	1800	(95.3%)
No	88	(4.7%)
<b>Travel modality</b>		
Foot	955	(50.6%)
Bicycle	51	(2.7%)
Motor Vehicle	468	(24.8%)
Unknown / not recorded	414	(21.9%)
<b>Reached patient</b>		
Yes – before ambulance	734	(38.9%)
Yes – after ambulance	609	(32.2%)
Yes – unknown	107	(5.7%)
No	334	(17.7%)
Unknown / not recorded	104	(5.5%)
<b>Patient sustained OHCA*</b>		
Yes	745	(39.4%)
No	723	(38.3%)
Unknown / not recorded	420	(22.3%)
<b>Assistance provided</b>		
Yes – CPR +/- AED	414	(21.9%)
Yes – “other”	782	(41.4%)
No	216	(11.5%)
Unknown / not recorded	142	(7.5%)
Did not reach patient	334	(17.7%)

\*responders sometimes able to determine OHCA status even if they did not reach patient's side (e.g. from bystanders, ambulance personnel etc.)

**Table 10.4: Actions after alert acceptance, by time of day and time of week (London)**

	Day	Night	Weekday	Weekend
<b>On-scene information</b>	<b>1180</b>	<b>708</b>	<b>1303</b>	<b>585</b>
<b>Reached scene</b>				
Yes	1122 (95.1%)	678 (95.8%)	1236 (94.9%)	564 (96.4%)
No	58 (4.9%)	30 (4.2%)	67 (5.1%)	21 (3.6%)
<b>Travel modality</b>				
Foot	580 (49.2%)	375 (53.0%)	652 (50.1%)	303 (51.8%)
Bicycle	26 (2.2%)	25 (3.5%)	38 (2.9%)	13 (2.2%)
Motor Vehicle	293 (24.8%)	175 (24.7%)	326 (25.0%)	142 (24.3%)
Unknown / not recorded	281 (23.8%)	133 (18.8%)	287 (22.0%)	127 (21.7%)
<b>Reached patient</b>				
Yes – before ambulance	444 (37.6%)	290 (41.0%)	505 (38.8%)	229 (39.2%)
Yes – after ambulance	371 (31.4%)	238 (33.6%)	410 (31.4%)	199 (34.0%)
Yes – unknown	79 (6.7%)	28 (3.9%)	79 (6.1%)	28 (4.8%)
No	226 (19.2%)	108 (15.3%)	245 (18.8%)	89 (15.2%)
Unknown / not recorded	60 (5.1%)	44 (6.2%)	64 (4.9%)	40 (6.8%)
<b>Patient sustained OHCA</b>				
Yes	468 (39.7%)	277 (39.1%)	521 (40.0%)	224 (38.3%)
No	444 (37.6%)	279 (39.4%)	490 (37.6%)	233 (39.8%)
Unknown / not recorded	268 (22.7%)	152 (21.5%)	292 (22.4%)	128 (21.9%)
<b>Assistance provided</b>				
Yes – CPR +/- AED	257 (21.8%)	157 (22.2%)	293 (22.5%)	121 (20.7%)
Yes – “other”	473 (40.1%)	309 (43.6%)	543 (41.7%)	239 (40.9%)
No	142 (12.0%)	74 (10.4%)	134 (10.3%)	82 (14.0%)
Unknown / not recorded	82 (6.9%)	60 (8.5%)	88 (6.7%)	54 (9.2%)
Did not reach patient	226 (19.2%)	108 (15.3%)	245 (18.8%)	89 (15.2%)

*GoodSAM responder travel distance*

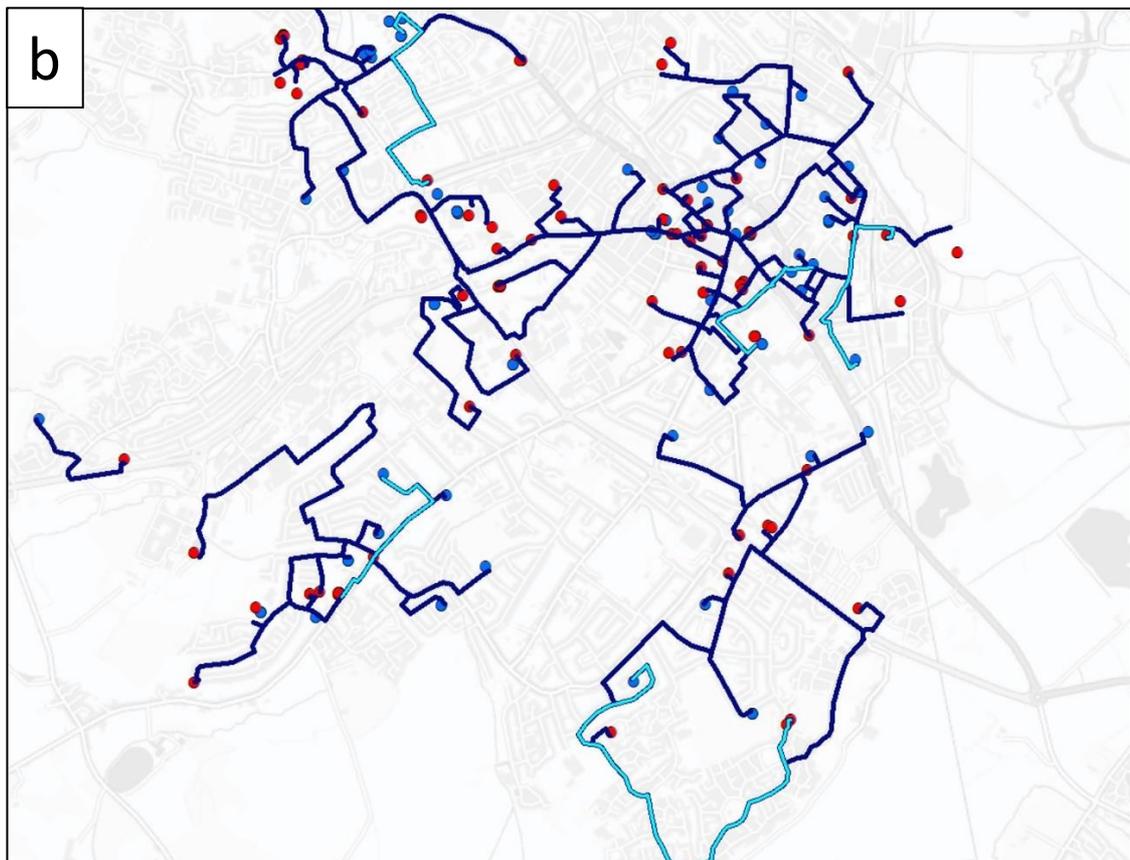
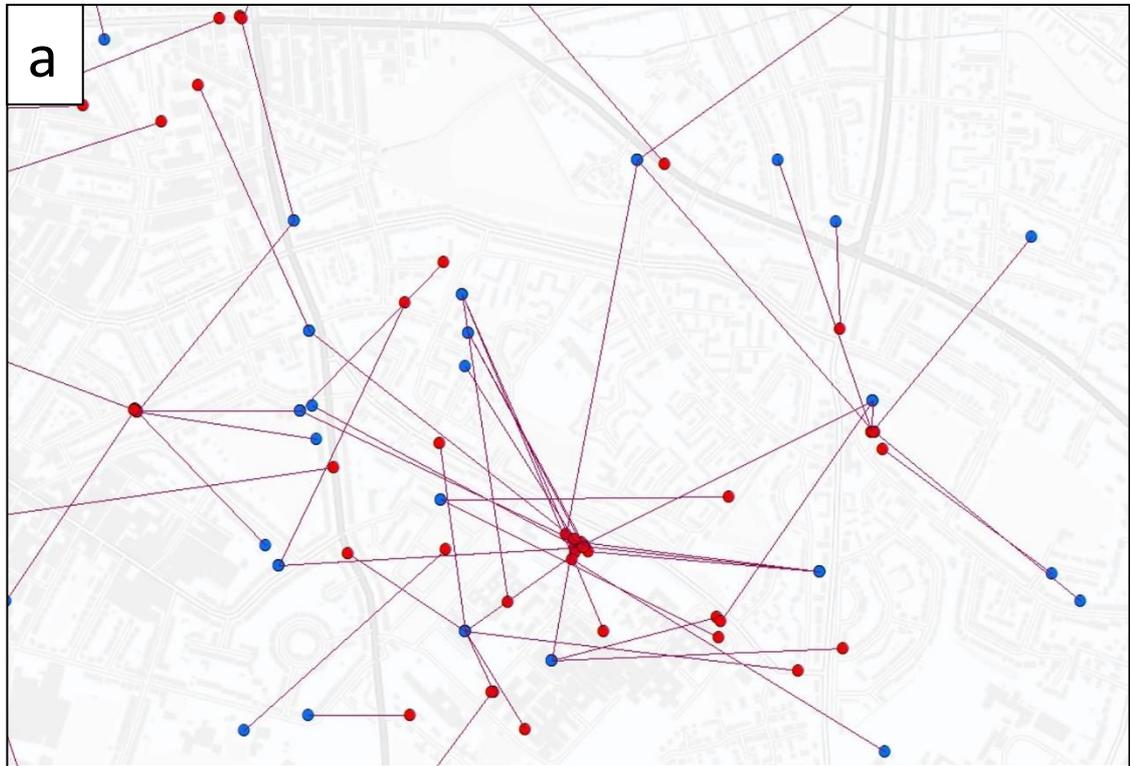
I was able to calculate the distance between the OHCA and the GoodSAM responder at the time of alert in 99% (9065/9180) cases. GoodSAM responder

location was missing in 115 cases. The median alerting (straight-line) distance was 379m (IQR 255-548m) and the median real-world travel distance was 601m (IQR 388-826m). I estimated a median response time of 6:01 min (IQR 3:53-8:16 min) at a brisk walking pace of 100m/min.

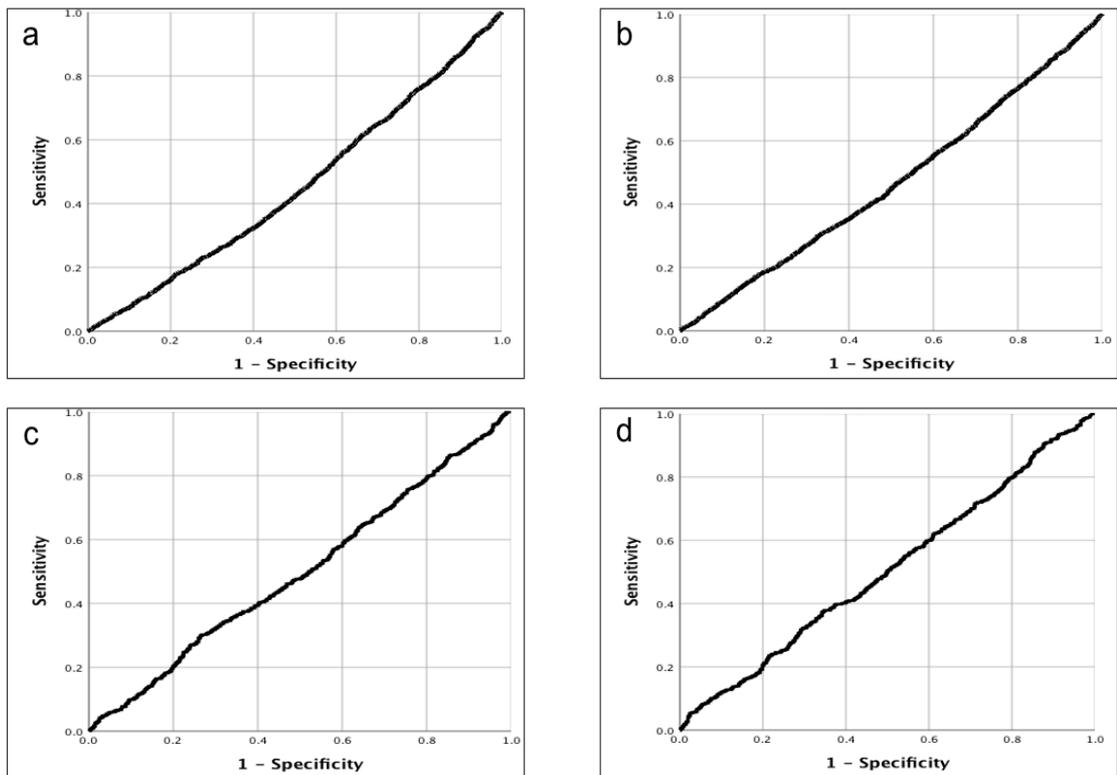
Examples in **Figures 10.1a** and **10.1b** illustrate how ArcGIS calculated a straight-line and real-world travel route from each GoodSAM responder to the corresponding alert.

Construction of ROC curves demonstrated that GoodSAM responder distance from the incident (either straight-line or real-world travel distance) did not reliably indicate whether a) an alert would be accepted (9065 cases: AUC 0.454 for straight line distance; 0.469 for real-world travel distance) or b) a GoodSAM responder would arrive at the patient's side before the ambulance (1638 cases, where before/after/did not arrive status was known: AUC 0.497 for straight line distance; 0.506 for real-world travel distance). Values for the AUC close to 0.5 and lines close to the diagonal suggest that responder travel distance is a poor predictor of the outcome of interest. **Figure 10.2(a-d) shows the curves.**

Given how poorly responder distance predicted alert acceptance or arrival at the patient's side before the ambulance service, I did not conduct individual analyses for each London borough.



**Figure 10.1: Straight-line (a, top) and real-world (b, bottom) travel distance. Some real-world travel routes have been highlighted (light blue) for ease of visualisation. (Blue dots = patient location, red dots = GoodSAM responder position at time of alert)**



**Figure 10.2: ROC curves. Effect of GoodSAM response distance on alert acceptance (London): a) straight line distance and alert acceptance; b) real-world travel distance and alert acceptance; c) straight line distance and arrival at patient before ambulance; d) real-world travel distance and arrival at patient before ambulance**

*Comparison with historical response radius*

I made a determination of how many alerts there would have been using the historical 300m alerting radius in London. There were 2967 alerts when the GoodSAM responder was within 300m – the previously used alerting radius in London – compared to 9065 alerts (where this distance was known) under the current alerting rules (up to 400m for Tier 3 responders or up to 700m for Tier 1 and 2 responders). There was statistical evidence of a slight decrease in alert acceptance rate (22% (2038/9065) alerts actually accepted compared to 25% (744/2967) with the 300m radius, OR 0.87, 95% CI 0.79-0.95;  $p=0.004$ ). With the 300m alerting radius GoodSAM responders who accepted an alert would have arrived at the patient’s side before the ambulance on 38% (255/678) vs 39% (718/1841) occasions (for cases where arrival status known, OR 0.96, 95% CI 0.80-1.16;  $p=0.70$ ), and provided CPR for OHCA on 54%

(133/245) vs 56% (406/731) occasions (for cases where OHCA status known, OR 0.95, 95% CI 0.71-1.27; p=0.73). **Table 10.5** details this further.

**Table 10.5: Alert outcome – current rules compared to historical radius (London)**

	<b>Current radius</b>	<b>Historical radius</b>
<b>Alert status</b>	<b>9065</b>	<b>2967</b>
Accepted	2038 (22.5%)	744 (25.0%)
Not seen	2411 (26.6%)	714 (24.1%)
Rejected	4616 (50.9%)	1509 (50.9%)
<b>On-scene information known</b>	<b>1841</b>	<b>678</b>
<b>Reached scene</b>		
Yes	1754 (95.3%)	644 (95.0%)
No	87 (4.7%)	34 (5.0%)
<b>Travel modality</b>		
Foot	946 (51.4%)	344 (50.7%)
Bicycle	51 (2.8%)	18 (2.7%)
Motor Vehicle	444 (24.1%)	134 (19.8%)
Unknown / not recorded	400 (21.7%)	182 (26.8%)
<b>Reached patient</b>		
Yes – before ambulance	718 (39.0%)	255 (37.6%)
Yes – after ambulance	594 (32.3%)	197 (29.1%)
Yes – unknown	101 (5.5%)	52 (7.7%)
No	326 (17.7%)	127 (18.7%)
Unknown / not recorded	102 (5.5%)	47 (6.9%)
<b>Patient sustained OHCA*</b>		
Yes	731 (39.7%)	245 (36.1%)
No	700 (38.0%)	268 (39.6%)
Unknown / not recorded	410 (22.3%)	165 (24.3%)
<b>Assistance provided</b>		
Yes – CPR +/- AED	406 (22.0%)	133 (19.6%)
Yes – “other”	756 (41.1%)	274 (40.4%)
No	214 (11.6%)	80 (11.8%)
Unknown / not recorded	139 (7.6%)	64 (9.5%)
Did not reach patient	326 (17.7%)	127 (18.7%)

#### **10.4.2 London – confirmed OHCAs**

There were 1233 OHCAs reported to the OHCAO registry between 20<sup>th</sup> September – 31<sup>st</sup> December 2019. GoodSAM sent out 5485 alerts for 2801 incidents in this time. There were 783 alerts for 398 OHCAs: so 14% (398/2801) incidents for which a GoodSAM alert was made were for confirmed OHCA, and 32% (398/1233) of the confirmed OHCAs received a GoodSAM alert. A GoodSAM responder accepted an alert on 20% (159/783) occasions for 11% (132/1233) total OHCA cases). More than one GoodSAM responder accepted an alert for 1.8% (22/1233) OHCAs: two accepted n=18, three n=3, four n=1.

GoodSAM responders who accepted an alert reached the scene on 91% (119/132) occasions (or 9.7%, 119/1233 of total OHCAs), and got to the patient on 81% (108/132) occasions (8.7% of total OHCAs). A GoodSAM responder (at least one) arrived before the ambulance on 40% (53/132) occasions (4.3% of total OHCAs), after the ambulance on 27% (36/132) occasions (2.9% of total OHCAs, with before/after status unknown for 14% (19/132) (1.5% of total OHCAs). More than one GoodSAM responder reached the patient's side on 9.8% (13/132) occasions (1.1% of total OHCAs); for 4 of these OHCAs this occurred before the ambulance arrived (two responders n=3, three n=1). Seventy GoodSAM responders provided CPR on 45% (60/132) occasions (4.9% of total OHCAs): 58% (31/53) OHCAs when (at least one responder) arrived before the ambulance, 31% (11/36) OHCAs when a responder arrived after the ambulance, and 95% (18/19) when before/after status was not known.

The median age of patients (n=1224, 9 unknown) was 68.5 years (IQR 53.0-80.9) and 65% (801/1231, 2 unknown) were male. The ambulance service witnessed 16% (198/1233) OHCAs, bystanders 52% (647/1233) and 31% (388/1233) were unwitnessed. Bystanders performed CPR in 56% (693/1233) OHCAs, or 67% (693/1035) of non-ambulance-service witnessed OHCAs. They attached an AED in 6.3% (77/1233) OHCAs, or 7.4% (77/1035) of non-ambulance-service witnessed OHCAs. 83% (1019/1228, 5 unknown) OHCAs

occurred in residential locations. The median ambulance response time (n=1232, 1 unknown) was 07:52 min (IQR 05:44-11:12 min). 62% (760/1233) OHCA occurred during the day and 67% (825/1233) on a weekday.

The initial cardiac rhythm (n=1222, 11 unknown) was VF/VT in 22% (264/1222), PEA in 32% (390/1222) and asystole in 46% (568/1222). ROSC (at hospital) was 32% (400/1233) and 8.0% (93/1166, 67 unknown) survived to hospital discharge.

**Table 10.6** further details process and outcome variables by GoodSAM alert status.

The logistic regression models contained 93% (1146/1233) of OHCA. There was no statistical evidence that acceptance of an alert (model 1) was associated with increased survival to hospital discharge (compared with no alert, AOR 1.02, 95% CI 0.44-2.39; p=0.96). There was also no statistical evidence of an effect on survival to hospital discharge when only considering OHCA for which a GoodSAM responder arrived at the patient before the ambulance service (AOR 1.39, 95% CI 0.39-4.93; p=0.61) (model 2). Lower age, EMS or bystander-witnessed OHCA (compared to unwitnessed), OHCA on a weekday (compared to a weekend), and an initial cardiac rhythm of VF/VT or PEA (compared to asystole) were statistically significant predictors of survival to hospital discharge. **Table 10.7(a-b)** details this further.

**Table 10.6: OHCA process and outcome variables by GoodSAM alert status (London)**

	GoodSAM alert		No GoodSAM alert (n=835)
	Accepted (n=132)	Not seen/rejected (n=266)	
<b>Age (median (IQR), yr)</b> Unknown cases	69.4 (52.7-80.0)	67.6 (51.1-79.7) 2	68.4 (53.7-81.3) 7
<b>Gender</b>			
Male	93 (70.5%)	172 (64.7%)	536 (64.3%)
Female	39 (29.5%)	94 (35.3%)	297 (35.7%)
Unknown cases			2
<b>OHCA witnessed by</b>			
EMS	1 (0.8%)	9 (3.4%)	188 (22.5%)
Bystander	80 (60.6%)	157 (59.0%)	410 (49.1%)
Unwitnessed	51 (38.6%)	100 (37.6%)	237 (28.4%)
<b>Bystander CPR</b>			
Yes	101 (76.5%)	187 (70.3%)	405 (48.5%)
No	31 (23.5%)	79 (29.7%)	430 (51.5%)
<i>Non EMS-witnessed</i>			
Yes	101 (77.1%) n=131	187 (72.8%) n=257	405 (62.6%) n=647
No	30 (22.9%)	70 (27.2%)	242 (37.4%)
<b>Bystander AED</b>			
Yes	10 (7.6%)	21 (7.9%)	46 (5.5%)
No	122 (92.4%)	245 (92.1%)	789 (94.5%)
<i>Non EMS-witnessed</i>			
Yes	10 (7.6%) n=131	21 (8.2%) n=257	46 (7.1%) n=647
No	121 (92.4%)	236 (91.8%)	601 (92.9%)
<b>Location type</b>			
Residential	98 (75.4%)	213 (80.1%)	708 (85.1%)
Non-residential	32 (24.6%)	53 (19.9%)	124 (14.9%)
Unknown cases	2		3
<b>Time of day</b>			
Day	88 (66.7%)	152 (57.1%)	520 (62.3%)
Night	44 (33.3%)	114 (42.9%)	315 (37.7%)
<b>Time of week</b>			
Weekday	94 (71.2%)	173 (65.0%)	558 (66.8%)
Weekend	38 (28.8%)	93 (35.0%)	277 (33.2%)
<b>Initial rhythm</b>			
VF-VT	33 (25.2%)	54 (20.4%)	177 (21.4%)
PEA	33 (25.2%)	72 (27.3%)	285 (34.5%)
Asystole	65 (49.6%)	138 (52.3%)	365 (44.1%)
Unknown cases	1	2	8
<b>EMS response time (median (IQR) mm:ss)</b> Unknown cases	06:55 (05:23-09:42)	07:00 (05:03-09:06)	08:21 (06:01-12:36) 1
<b>ROSC at hospital</b>			
Yes	40 (30.3%)	74 (27.8%)	286 (34.3%)
No	92 (69.7%)	192 (72.2%)	549 (65.7%)
<b>Survival to hospital discharge</b>			
Yes	11 (8.8%)	12 (4.6%)	70 (9.0%)
No	114 (91.2%)	247 (95.4%)	712 (91.0%)
Unknown cases	7	7	53

**Table 10.7a (Model 1) and 10.7b (Model 2): Logistic regression models: adjusted odds ratios (AOR) for survival to hospital discharge (London)**

a) MODEL 1	Unadjusted OR (95% CI)	AOR (95% CI)
<b>GoodSAM group</b>		
Accepted	0.98 (0.50-1.91); p=0.96	1.02 (0.44-2.39); p=0.96
Not seen/rejected	0.49 (0.26-0.93); p=0.03	0.51 (0.23-1.11); p=0.09
No alert	Reference	Reference
<b>Age in years</b>	0.98 (0.97-0.99); p<0.001	0.97 (0.96-0.98); <b>p&lt;0.001</b>
<b>Gender</b>		
Male	1.19 (0.76-1.87); p=0.45	0.61 (0.35-1.07); p=0.09
Female	Reference	Reference
<b>OHCA witnessed status</b>		
EMS	10.9 (4.67-25.3); p<0.001	12.9 (4.09-40.5); <b>p&lt;0.001</b>
Bystander	5.46 (2.46-12.1); p<0.001	3.56 (1.42-8.93); <b>p=0.007</b>
Unwitnessed	Reference	Reference
<b>CPR performed by</b>		
EMS	4.86 (2.47-9.59); p<0.001	<i>Not calculated*</i>
Bystander	1.98 (1.06-3.70); p=0.03	1.29 (0.63-2.65); p=0.49
Not performed	Reference	Reference
<b>Bystander AED</b>		
Yes	0.70 (0.25-1.96); p=0.49	0.30 (0.09-1.07); p=0.06
No	Reference	Reference
<b>Location type</b>		
Non-residential	2.21 (1.36-3.57); p=0.001	1.47 (0.78-2.76); p=0.24
Residential	Reference	Reference
<b>Time of day</b>		
Day	1.56 (0.98-2.47); p=0.06	1.58 (0.89-2.79); p=0.12
Night	Reference	Reference
<b>Time of week</b>		
Weekday	1.42 (0.88-2.30); p=0.15	1.84 (1.04-3.27); p=0.04
Weekend	Reference	Reference
<b>Initial rhythm</b>		
VF/VT	29.8 (13.4-66.3); p<0.001	28.5 (12.1-67.6); <b>p&lt; 0.001</b>
PEA	3.93 (1.63-9.51); p=0.002	2.71 (1.06-6.92); <b>p=0.04</b>
Asystole	Reference	Reference
<b>EMS response time</b>	1.00 (1.00-1.00); p=0.61	1.00 (0.99-1.00); p=0.86

<b>b) MODEL 2</b>	<b>Unadjusted OR (95% CI)</b>	<b>AOR (95% CI)</b>
<b>GoodSAM group</b>		
At patient before EMS	1.16 (0.44-3.01); p=0.77	1.39 (0.39-4.93); p=0.61
All other accepted	0.87 (0.37-2.08); p=0.76	0.86 (0.30-2.43); p=0.77
Not seen/rejected	0.49 (0.26-0.93); p=0.03	0.51 (0.24-1.11); p=0.09
No alert	Reference	Reference
<b>Age in years</b>	0.98 (0.97-0.99); p<0.001	0.97 (0.96-0.98); <b>p&lt;0.001</b>
<b>Gender</b>		
Male	1.19 (0.76-1.87); p=0.45	0.62 (0.35-1.08); p=0.09
Female	Reference	Reference
<b>OHCA witnessed status</b>		
EMS	10.8 (4.51-25.0); p<0.001	12.4 (3.95-39.2); <b>p&lt;0.001</b>
Bystander	5.46 (2.46-12.1); p<0.001	3.47 (1.38-8.73); <b>p=0.008</b>
Unwitnessed	Reference	Reference
<b>CPR performed by</b>		
EMS	4.86 (2.47-9.59); p<0.001	<i>Not calculated*</i>
Bystander	1.98 (1.06-3.70); p=0.03	1.26 (0.61-2.60); p=0.53
Not performed	Reference	Reference
<b>Bystander AED</b>		
Yes	0.70 (0.25-1.96); p=0.49	0.30 (0.09-1.08); p=0.07
No	Reference	Reference
<b>Location type</b>		
Non-residential	2.21 (1.36-3.57); p=0.001	1.45 (0.77-2.74); p=0.25
Residential	Reference	Reference
<b>Time of day</b>		
Day	1.56 (0.98-2.47); p=0.06	1.58 (0.90-2.81); p=0.11
Night	Reference	Reference
<b>Time of week</b>		
Weekday	1.42 (0.88-2.30); p=0.15	1.84 (1.04-3.27); <b>p=0.04</b>
Weekend	Reference	Reference
<b>Initial rhythm</b>		
VF/VT	29.8 (13.4-66.3); p<0.001	28.9 (12.2-68.5); <b>p&lt;0.001</b>
PEA	3.93 (1.63-9.51); p=0.002	2.73 (1.07-6.96); <b>p=0.04</b>
Asystole	Reference	Reference
<b>EMS response time</b>	1.00 (1.00-1.00); p=0.61	1.00 (0.99-1.00); p=0.87

\*EMS performed CPR for all of the cases that were EMS-witnessed, therefore not calculated by SPSS (redundancy)

The continuous variables of age and ambulance service response time were both non-normally distributed (Shapiro-Wilk test for normality, both p <0.001). There was a positive skew for ambulance service response time (more values at shorter response times: Skewness +5.72) and a negative skew for age (more values at older ages: Skewness -0.851).

Tests for multicollinearity suggested that there was little correlation between the independent variables tested: the largest variance inflation factor (VIF) in either model was 1.69. Cox & Snell  $R^2$  (model 1: 0.161; model 2: 0.161) and Nagelkerke  $R^2$  (model 1: 0.380; model 2: 0.381) suggest that 16-38% of the variation in survival to hospital discharge can be explained by both model 1 and model 2. The non-significant p-values for the Hosmer-Lemeshow Goodness of Fit test (model 1: 0.562; model 2: 0.525) suggest overall goodness of fit for both models.

### **10.4.3 East Midlands – all GoodSAM alerts**

There were 8006 GoodSAM alerts reported for 4254 incidents between 20<sup>th</sup> September 2019 – 17<sup>th</sup> March 2020. After excluding 3.3% (265/8006) alerts that were sent to an EMAS employee already attending that incident whilst on-duty, there were 7741 alerts for 4177 incidents.

61% (4703/7741) alerts were sent during the day, and 67% (5197/7741) on a weekday. Overall, GoodSAM responders accepted 29% of alerts (2252/7741); 23% (1739) were rejected and 48% (3750) were not seen. There was some statistical evidence that GoodSAM responders were more likely to accept an alert during the day than at night (OR 1.22, 95% CI 1.10-1.35;  $p=0.0002$ ) but no evidence that responders were more or less likely to accept an alert on a weekday compared to the weekend (OR 1.00, 95% CI 0.90-1.11;  $p=0.99$ ). There was no statistical evidence that multiple acceptances were more or less likely during the day than at night (OR 1.20, 95% CI 0.96-1.49;  $p=0.11$ ), nor on a weekday compared to the weekend (OR 1.06, 95% CI 0.84-1.32;  $p=0.63$ ).

**Table 10.8** details this further.

**Table 10.8: GoodSAM alert outcome (East Midlands)**

	Alerts	Multiple Accepted	Accepted	Rejected	Not seen
<b>Total</b>	<b>7741</b>	<b>369 (4.8%)</b>	<b>2252 (29.1%)</b>	<b>1739 (22.5%)</b>	<b>3750 (48.4%)</b>
Day	4703 (60.8%)	239 (5.1%)	1442 (30.6%)	1080 (23.0%)	2181 (46.4%)
Night	3038 (39.2%)	130 (4.3%)	810 (26.7%)	659 (21.7%)	1569 (51.6%)
Weekday	5197 (67.1%)	252 (4.8%)	1512 (29.1%)	1219 (23.5%)	2466 (47.4%)
Weekend	2544 (32.9%)	117 (4.6%)	740 (29.1%)	520 (20.4%)	1284 (50.5%)

More than one GoodSAM responder accepted an alert on 4.8% (369/7741) occasions: two people accepted, n=308; three, n=48; four, n=11; five, n=1; six, n=1.

I was able to map 99% (7668/7741) alerts to one of the 11 East Midlands counties or unitary authorities. I was able to map all of the remaining 73 alerts but these occurred outside of the EMAS operational area. The range of alerts accepted was 18-59%, rejected 0-25% and not seen 41-58%. The range of multiple alert acceptances was 0.7-7.4%. **Table 10.9** details this further.

**Table 10.9: GoodSAM alert outcome by East Midlands county or unitary authority**

	Alerts	Multiple Accepted	Accepted	Rejected	Not seen
<b>Total</b>	<b>7668</b>	<b>368 (4.8%)</b>	<b>2239 (29.2%)</b>	<b>1710 (22.3%)</b>	<b>3719 (48.5%)</b>
Derby	406	20 (4.9%)	140 (34.5%)	74 (18.2%)	192 (47.3%)
Derbyshire	729	36 (4.9%)	249 (34.2%)	159 (21.8%)	321 (44.0%)
Leicester	1157	39 (3.4%)	202 (17.5%)	292 (25.2%)	663 (57.3%)
Leicestershire	788	46 (5.8%)	273 (34.7%)	168 (21.3%)	347 (44.0%)
Lincolnshire	1227	55 (4.5%)	342 (27.9%)	300 (24.4%)	585 (47.7%)
North Lincolnshire	144	1 (0.7%)	30 (20.8%)	30 (20.8%)	84 (58.4%)
North East Lincolnshire	251	4 (1.6%)	81 (32.3%)	61 (24.3%)	109 (43.4%)
Northamptonshire	1280	73 (5.7%)	391 (30.5%)	266 (20.8%)	623 (48.7%)
Nottingham	820	56 (6.8%)	244 (29.8%)	170 (20.7%)	406 (49.5%)
Nottinghamshire	839	36 (4.3%)	271 (32.3%)	190 (22.6%)	378 (45.1%)
Rutland	27	2 (7.4%)	16 (59.3%)	0 (0%)	11 (40.7%)

### *GoodSAM responder actions*

GoodSAM responders who accepted an alert (n=2252) completed the post-alert Survey Monkey questionnaire on 78% (1758/2252) occasions. I was able to determine on-scene status from in-app records on a further 188 occasions – for a total of 86% (1946/2252) of all accepted alerts.

In total, 81% (1824/2252) GoodSAM responders accepting an alert reported reaching the scene – or 94% (1824/1946) of responders where the information was known. There were 75% (1682/2252) – or 86% (1682/1946) – who reached the patient: 1227 (54% or 63%) before the ambulance service, 312 (14% or 16%) after, with before/after status unknown in 143 (6.4% or 7.3%). The majority of responders travelled to scene by motorised vehicle (62%, 1214/1946). GoodSAM responders indicated that the patient was in OHCA on 55% (1068/1946) occasions. In these 1068 reported OHCA, a GoodSAM responder reached the patient's side on 1050 occasions: they provided CPR +/- defibrillation on 74% (564/759) occasions when they reached the patient before the ambulance service, 30.5% (61/200) when they reached the patient after the ambulance and 60% (55/91) when their arrival time at the patient's side was unknown. **Table 10.10** describes responses from the post-event questionnaire further.

**Table 10.11** further stratifies actions after alert acceptance by day/night and by weekday/weekend. There was no statistical evidence that GoodSAM responders were more or less likely to reach the scene in the day compared to the night (OR 0.92, 95% CI 0.63-1.35; p=0.67), or on a weekday compared to the weekend (OR 1.24, 95% CI 0.85-1.82; p=0.26).

Similarly there was no statistical evidence (in all cases, calculated from cases where arrival status data was known) of a difference in day versus night for arriving before the ambulance (OR 1.15, 95% CI 0.93-1.42; p=0.19) or providing CPR/AED for OHCA cases (OR 0.89, 95% CI 0.68-1.16; p=0.39); and no difference in weekday versus weekend for arriving before the

ambulance (OR 1.07, 95% CI 0.86-1.33; p=0.56) or providing CPR/AED for OHCA cases (OR 0.96, 95% CI 0.73-1.26; p=0.77)

**Table 10.10: Actions after alert acceptance (East Midlands)**

	Number (%)
<b>On-scene information known</b>	<b>1946</b>
<b>Reached scene</b>	
Yes	1824 (93.7%)
No	122 (6.3%)
<b>Travel modality</b>	
Foot	375 (19.3%)
Bicycle	23 (1.2%)
Motor Vehicle	1214 (62.4%)
Other	5 (0.2%)
Unknown / not recorded	329 (16.9%)
<b>Reached patient</b>	
Yes – before ambulance	1227 (63.1%)
Yes – after ambulance	312 (16.0%)
Yes – unknown	145 (7.5%)
No	207 (10.6%)
Unknown / not recorded	55 (2.8%)
<b>Patient sustained OHCA*</b>	
Yes	1068 (54.9%)
No	639 (32.8%)
Unknown / not recorded	239 (12.3%)
<b>Assistance provided</b>	
Yes – CPR +/- AED	680 (34.9%)
Yes – “other”	853 (43.8%)
No	125 (6.4%)
Unknown / not recorded	84 (4.4%)
Did not reach patient	204 (10.5%)

\*responders sometimes able to determine OHCA status even if they did not reach patient’s side (e.g. from bystanders, ambulance personnel etc.)

**Table 10.11: Actions after alert acceptance, by time of day and time of week  
(East Midlands)**

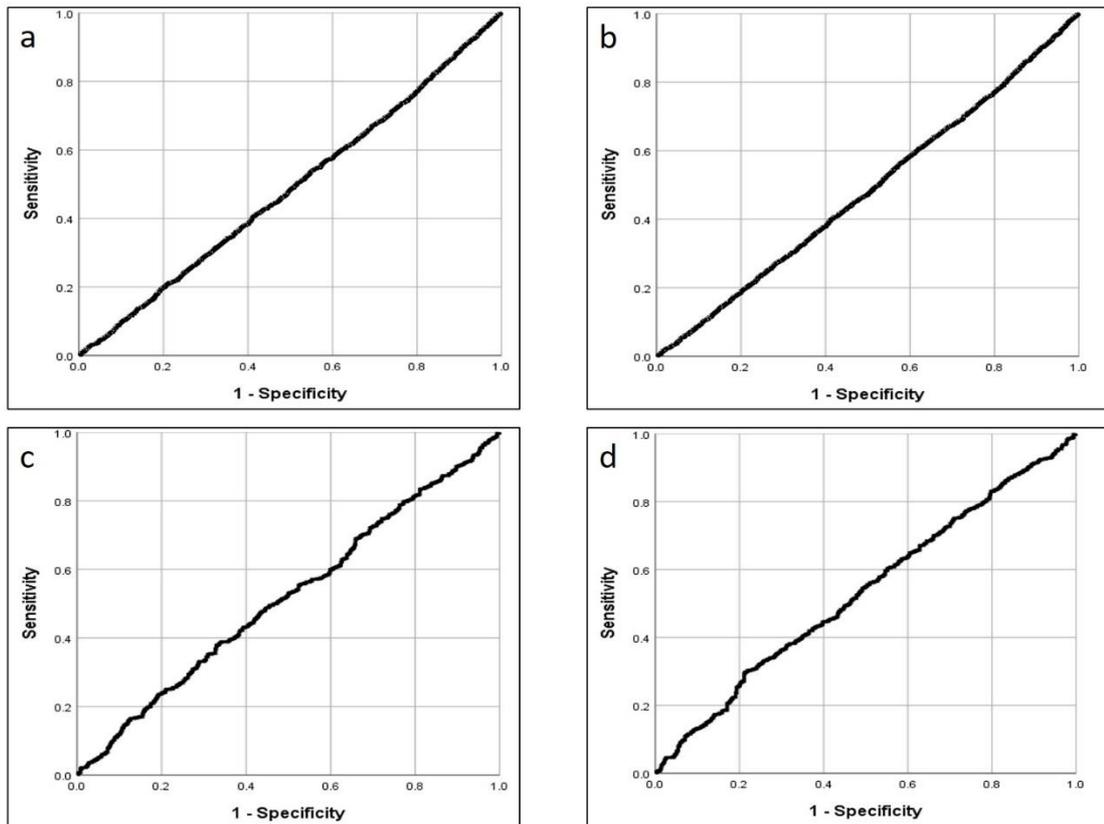
	<b>Day</b>	<b>Night</b>	<b>Weekday</b>	<b>Weekend</b>
<b>On-scene information</b>	<b>1225</b>	<b>721</b>	<b>1317</b>	<b>629</b>
<b>Reached scene</b>				
Yes	1146 (93.6%)	678 (94.0%)	1240 (94.2%)	584 (92.8%)
No	79 (6.4%)	43 (6.0%)	77 (5.8%)	45 (7.2%)
<b>Travel modality</b>				
Foot	232 (18.9%)	143 (19.8%)	255 (19.4%)	120 (19.1%)
Bicycle	15 (1.2%)	8 (1.1%)	19 (1.4%)	4 (0.6%)
Motor Vehicle	765 (62.5%)	449 (62.3%)	823 (62.5%)	391 (62.2%)
Other	1 (0.1%)	4 (0.6%)	4 (0.3%)	1 (0.1%)
Unknown / not recorded	212 (17.3%)	117 (16.2%)	216 (16.4%)	113 (18.0%)
<b>Reached patient</b>				
Yes – before ambulance	783 (63.9%)	444 (61.6%)	838 (63.6%)	389 (61.9%)
Yes – after ambulance	182 (14.9%)	130 (18.0%)	217 (16.5%)	95 (15.1%)
Yes – unknown	92 (7.5%)	53 (7.4%)	92 (7.0%)	53 (8.4%)
No	132 (10.8%)	75 (10.4%)	130 (9.9%)	77 (12.2%)
Unknown / not recorded	36 (2.9%)	19 (2.6%)	40 (3.0%)	15 (2.4%)
<b>Patient sustained OHCA</b>				
Yes	698 (57.0%)	370 (51.3%)	743 (56.4%)	325 (51.7%)
No	375 (30.6%)	264 (36.6%)	424 (32.2%)	215 (34.2%)
Unknown / not recorded	152 (12.4%)	87 (12.1%)	150 (11.4%)	89 (14.1%)
<b>Assistance provided</b>				
Yes – CPR +/- AED	438 (35.8%)	242 (33.6%)	471 (35.8%)	209 (33.2%)
Yes – “other”	531 (43.3%)	322 (44.6%)	576 (43.7%)	277 (44.1%)
No	70 (5.7%)	55 (7.6%)	82 (6.2%)	43 (6.8%)
Unknown / not recorded	56 (4.6%)	28 (3.9%)	60 (4.6%)	24 (3.8%)
Did not reach patient	130 (10.6%)	74 (10.3%)	128 (9.7%)	76 (12.1%)

### *GoodSAM responder travel distance*

I was able to calculate the distance between the OHCA and the GoodSAM responder at the time of alert in 99% (7637/7741) cases. GoodSAM responder location was missing in 104 cases. The median alerting (straight-line) distance was 523m (IQR 341-773m) and the median real-world travel distance was 814m (IQR 553-1077m). I estimated a median response time of 8:08 min (IQR 5:32-10:46 min) at a brisk walking pace of 100m/min.

Construction of ROC curves demonstrated that GoodSAM responder distance from the incident (either straight-line or real-world travel distance) did not reliably indicate whether a) an alert would be accepted (7637 cases: AUC 0.486 for straight line distance; 0.483 for real-world travel distance) or b) a GoodSAM responder would arrive at the patient's side before the ambulance (1720 cases, where before/after/did not arrive status was known: AUC 0.517 for straight line distance; 0.533 for real-world travel distance). Values for the AUC close to 0.5 and lines close to the diagonal suggest that responder travel distance is a poor predictor of the outcome of interest. **Figure 10.3(a-d) shows the curves.**

Given how poorly responder distance predicted alert acceptance or arrival at the patient's side before the ambulance service, I did not conduct individual analyses for each county or unitary authority.



**Figure 10.3: ROC curves. Effect of GoodSAM response distance on alert acceptance (East Midlands): a) straight line distance and alert acceptance; b) real-world travel distance and alert acceptance; c) straight line distance and arrival at patient before ambulance; d) real-world travel distance and arrival at patient before ambulance**

#### **10.4.4 East Midlands – confirmed OHCAs**

There were 867 OHCAs reported to the OHCAO registry between 20<sup>th</sup> September – 31<sup>st</sup> December 2019. GoodSAM sent out 4740 alerts for 2515 incidents in this time. There were location data available for the 82% (707/867) OHCAs in residential locations. There were 369 alerts for 232 residential OHCAs: so 9.2% (232/2515) incidents for which a GoodSAM alert was made were for confirmed residential OHCAs, and 33% (232/707) of the confirmed residential OHCAs received a GoodSAM alert. A GoodSAM responder accepted an alert on 24% (89/369) occasions for 11% (77/707) of the total residential OHCAs. More than one GoodSAM responder accepted an alert for 1.4% (10/707) OHCAs: two accepted n=8, three n=2.

GoodSAM responders who accepted an alert reached the scene on 83% (64/77) occasions (or 9.1%, 64/707 of total residential OHCAs), and got to the patient on 78% (60/77) occasions (8.5% of total OHCAs): a responder (at least one) arrived before the ambulance on 53% (41/77) occasions (5.8% of total OHCAs), after the ambulance on 17% (13/77) occasions (1.8% of total OHCAs), with before/after status unknown on 7.8% (6/77) occasions (0.8% of total OHCAs). More than one GoodSAM responder reached the patient's side on 9.1% (7/77) occasions (1.0% of total OHCAs); for one of these OHCAs two responders arrived before the ambulance. Forty-nine GoodSAM responders provided CPR/AED on 57% (44/77) occasions (6.2% of total OHCAs): 83% (34/41) OHCAs when (at least one responder) arrived before the ambulance, 38% (5/13) when a responder arrived after the ambulance, and 83% (5/6) when before/after status was not known.

The median age of patients (n=705, 2 unknown) was 72.9 years (IQR 61.1-81.2) and 58% (412/705, 2 unknown) were male. Bystanders witnessed 43% (304/707) residential OHCAs, and performed CPR in 59% (420/707). Data on bystander AED use were not available. The median ambulance response time (n=700, 7 unknown) was 09:36min (IQR 06:32-14:57 min). 58% (408/707) residential OHCAs occurred during the day and 67% (478/707) on a weekday.

The initial cardiac rhythm (n=678, 29 unknown) was VF/VT in 14% (97/678), PEA in 24% (164/678) and asystole in 62% (417/678). ROSC (at hospital) was 26% (187/707) and 4.8% (34/702, 5 unknown) survived to hospital discharge.

**Table 10.12** further details process and outcome variables by GoodSAM alert status.

**Table 10.12: OHCA process and outcome variables by GoodSAM alert status  
(East Midlands)**

	GoodSAM alert				No GoodSAM alert (n=475)	
	Accepted (n=77)		'Not seen' or rejected (n=155)			
<b>Age (median (IQR), yr)</b> Unknown cases	72.1	(54.9-78.7)	74.4	(56.8-83.5)	72.8	(62.6-80.7)
			1			
<b>Gender</b>						
Male	49	(63.6%)	94	(60.6%)	269	(56.9%)
Female	28	(36.4%)	61	(39.4%)	204	(43.1%)
Unknown cases					2	
<b>OHCA witnessed by</b>						
Bystander	39	(50.6%)	69	(44.5%)	196	(41.3%)
Unwitnessed*	38	(49.4%)	86	(55.5%)	279	(58.7%)
<b>Bystander CPR</b> <i>All cases</i>						
Yes	50	(64.9%)	105	(67.7%)	265	(55.8%)
No <sup>+</sup>	27	(35.1%)	50	(32.3%)	210	(44.2%)
<b>Time of day</b>						
Day	48	(62.3%)	83	(53.5%)	277	(58.3%)
Night	29	(37.7%)	72	(46.5%)	198	(41.7%)
<b>Time of week</b>						
Weekday	53	(68.8%)	105	(67.7%)	320	(67.4%)
Weekend	24	(31.2%)	50	(32.3%)	155	(32.6%)
<b>Initial rhythm</b>						
VF-VT	11	(15.3%)	18	(12.2%)	68	(14.8%)
PEA	17	(23.6%)	25	(17.0%)	122	(26.6%)
Asystole	44	(61.1%)	104	(70.8%)	269	(58.6%)
Unknown cases	5		8		16	
<b>EMS response time (median (IQR) mm:ss)</b> Unknown cases	09:19	(06:32-14:04)	09:07	(06:15-12:44)	09:55	(06:38-15:16)
					7	
<b>ROSC at hospital</b>						
Yes	18	(23.4%)	37	(23.9%)	132	(27.8%)
No	59	(76.6%)	118	(76.1%)	343	(72.2%)
<b>Survival to hospital discharge</b>						
Yes	4	(5.2%)	5	(3.3%)	25	(5.3%)
No	73	(94.8%)	147	(96.7%)	448	(94.7%)
Unknown cases			3		2	

\* Will include unwitnessed and EMS-witnessed OHCA's

+ Will include cases where EMS initiated CPR

The logistic regression models contained 94% (665/707) of residential OHCA's. There was no statistical evidence that acceptance of an alert (model 1) was associated with increased survival to hospital discharge (compared with no alert, AOR 1.06, 95% CI 0.31-3.56; p=0.93). There was also no

statistical evidence of an effect on survival to hospital discharge when only considering OHCA for which a GoodSAM responder arrived at the patient before the ambulance service (AOR 0.66, 95% CI 0.08-5.65; p=0.70) (model 2). Lower age and an initial cardiac rhythm of VF/VT (compared to asystole) were statistically significant predictors of survival to hospital discharge. **Table 10.13(a-b)** details this further.

OHCA witnessed status and bystander CPR were not included in the logistic regression models, as described in the methods. For interest, including these factors in the models did not materially affect the findings: acceptance of an alert and arrival on the scene before the ambulance service still were not associated with increased survival to hospital discharge, and lower age and an initial cardiac rhythm of VF/VT (compared to asystole) were still the only statistically significant predictors of survival to hospital discharge.

**Table 10.13a (Model 1) and 10.13b (Model 2): Logistic regression models: adjusted odds ratios (AOR) for survival to hospital discharge (East Midlands)**

<b>a) MODEL 1</b>	<b>Unadjusted OR (95% CI)</b>	<b>AOR (95% CI)</b>
<b>GoodSAM group</b>		
Accepted	0.98 (0.33-2.90); p=0.97	1.06 (0.31-3.56); p=0.93
Not seen/rejected	0.61 (0.23-1.62); p=0.32	0.59 (0.19-1.85); p=0.37
No alert	Reference	Reference
<b>Age in years</b>	0.98 (0.96-0.99); p=0.001	0.96 (0.94-0.98); <b>p&lt;0.001</b>
<b>Gender</b>		
Male	2.42 (1.08-5.42); p=0.03	1.19 (0.48-2.98); p=0.71
Female	Reference	Reference
<b>Time of day</b>		
Day	1.20 (0.59-2.43); p=0.62	1.49 (0.64-3.43); p=0.35
Night	Reference	Reference
<b>Time of week</b>		
Weekday	0.99 (0.48-2.07); p=0.98	1.07 (0.45-2.58); p=0.88
Weekend	Reference	Reference
<b>Initial rhythm</b>		
VF/VT	27.7 (10.2-75.0); p<0.001	38.1 (12.5-116.9); <b>p&lt;0.001</b>
PEA	1.53 (0.36-6.47); p=0.57	2.16 (0.49-9.62); p=0.31
Asystole	Reference	Reference
<b>EMS response time</b>	1.00 (0.999-1.00); p=0.78	1.00 (0.999-1.00); p=0.78

<b>b) MODEL 2</b>	<b>Unadjusted OR (95% CI)</b>	<b>AOR (95% CI)</b>
<b>GoodSAM group</b>		
At patient before EMS	0.45 (0.06-3.39); p=0.44	0.66 (0.08-5.65); p=0.70
All other accepted	1.63 (0.47-5.68); p=0.45	1.35 (0.33-5.60); p=0.68
Not seen/rejected	0.61 (0.23-1.62); p=0.32	0.59 (0.19-1.86); p=0.37
No alert	Reference	Reference
<b>Age in years</b>	0.98 (0.96-0.99); p=0.001	0.96 (0.94-0.98); <b>p&lt;0.001</b>
<b>Gender</b>		
Male	2.42 (1.08-5.42); p=0.03	1.21 (0.48-3.04); p=0.68
Female	Reference	Reference
<b>Time of day</b>		
Day	1.20 (0.59-2.43); p=0.62	1.46 (0.63-3.39); p=0.38
Night	Reference	Reference
<b>Time of week</b>		
Weekday	0.99 (0.48-2.07); p=0.98	1.07 (0.44-2.57); p=0.89
Weekend	Reference	Reference
<b>Initial rhythm</b>		
VF/VT	27.7 (10.2-75.0); p<0.001	37.8 (12.3-116.1); <b>p&lt;0.001</b>
PEA	1.53 (0.36-6.47); p=0.57	2.20 (0.49-9.84); p=0.30
Asystole	Reference	Reference
<b>EMS response time</b>	1.00 (0.999-1.00); p=0.78	1.00 (0.999-1.00); p=0.79

The continuous variables of age and ambulance service response time were both non-normally distributed (Shapiro-Wilk test for normality, both  $p < 0.001$ ). There was a positive skew for ambulance service response time (more values at shorter response times: Skewness +7.31) and a negative skew for age (more values at older ages: Skewness -1.46).

Tests for multicollinearity suggested that there was little correlation between the independent variables tested: the largest variance inflation factor (VIF) in either model was 1.69. Cox & Snell  $R^2$  (model 1: 0.116; model 2: 0.116) and Nagelkerke  $R^2$  (model 1: 0.362; model 2: 0.364) suggest that 12-36% of the variation in survival to hospital discharge can be explained by both model 1 and model 2. The non-significant p-values for the Hosmer-Lemeshow Goodness of Fit test (model 1: 0.969; model 2: 0.971) suggest overall goodness of fit for both models.

### 10.4.5 Data validation

There were two main areas where I deemed manual changes to the data necessary.

Alert status was updated where it was clear that a responder had reached the scene of an incident, but had indicated that they had rejected or not seen an alert. In London, this increased the number of acceptances from 894 to 2088, and in East Midlands from 1277 to 2252. This is detailed in **Table 10.14**

**Table 10.14: Alert status, before and after manual correction**

	London (n=9180)		East Midlands (n=7741)	
	Original response	After correction	Original response	After correction
Accepted	1292 (14.1%)	2088 (22.7%)	1277 (16.5%)	2252 (29.1%)
Not seen	5235 (57.0%)	4650 (50.7%)	1995 (25.8%)	1739 (22.5%)
Rejected	2653 (28.9%)	2442 (26.6%)	4469 (57.7%)	3750 (48.4%)

There were also occasions where there were discrepancies between the Survey Monkey questionnaire and the post-event in-app feedback. In London, there were 47 discrepancies (from 495 occasions when both were completed, 9.5%), and in East Midlands there were 35 discrepancies (from 288 occasions when both were completed, 12%).

## 10.5 DISCUSSION

### 10.5.1 Main findings

GoodSAM responders accept a minority of alerts (23% LAS, 29% EMAS) and there were very few incidents where more than one person accepted an alert (3.3% LAS, 4.8% EMAS). In both ambulance services, around half of GoodSAM alerts were 'not seen' and a quarter were rejected.

There were local differences in acceptance rates (at borough, county or unitary authority level) in both ambulance service areas. Alert acceptance was more likely during the day in both ambulance services and multiple alert acceptance was more likely during the day in London. There were no differences between weekdays and weekends. The time of day or week made no difference to arriving at scene or at the patient before the ambulance service, nor to the provision of CPR and/or defibrillation in OHCA's.

The majority of those accepting alerts reach the scene (95% LAS and 94% EMAS) and the patient's side (77% LAS and 86% EMAS). In London, 39% reached the patient before the ambulance service and in East Midlands 63% did. Those reaching the patient performed CPR and/or defibrillation more often than not (LAS 56%, EMAS 64%), with many more providing 'other' assistance that was not fully defined here. Even when arriving after the ambulance service, many GoodSAM responders were able to provide CPR/defibrillation or 'other' assistance.

I was unable to determine a distance threshold to reliably predict how far away a GoodSAM responder could be from an incident before they would not accept an alert and/or arrive at the patient before the ambulance service. Calculating real-world travel distance (compared to the straight-line estimate) increased median travel distance by 222m in London and 291m in East Midlands. However, use of real-world travel distance rather than straight-line estimates made no meaningful difference to ROC curves and the efforts to determine the response distance threshold.

In London, I estimated that the current practice of alerting GoodSAM responders up to a 700m radius, compared to the historical 300m radius, resulted in many more accepted alerts (2038 vs 744) with only a small decline in the acceptance *rate* (23% vs 25%). There was no effect on getting to the patient before the ambulance and providing CPR and/or defibrillation in OHCA's.

There was no statistical evidence in either ambulance service – all OHCA for LAS, residential OHCA only for EMAS – that acceptance of a GoodSAM alert or arriving at the patient before the ambulance service was associated with improved survival to hospital discharge. In both ambulance services, GoodSAM responders accepted an alert for 11% of confirmed OHCA, with multiple acceptances for 1.8% (LAS) and 1.4% (EMAS). Only a minority of GoodSAM alerts (September – December 2019) were for confirmed OHCA (14% LAS and 9.2% EMAS), and for only a minority of alerts was a GoodSAM responder close enough to receive an alert (32% LAS, 33% EMAS).

### **10.5.2 Comparison with the literature**

In this chapter I have been unable to validate the finding in **chapter 6** that acceptance of a GoodSAM alert was associated with improved survival to hospital discharge.

In contrast to the work in **chapter 6**, I calculated whether an OHCA had occurred during day or night or on a weekday or weekend. There is evidence that survival to hospital discharge following OHCA is significantly higher for OHCA during the day rather than at night ([382](#)), and conflicting evidence on the effect of weekend versus weekday ([383-385](#)). In this chapter the time of day was *not* associated with improved survival to hospital discharge in either ambulance service. There was an association between weekday OHCA and improved survival to hospital discharge in London only.

In considering only three months of OHCA data, it may be that there was a seasonal effect to OHCA outcome – it has been previously reported that OHCA survival is lower in the winter, for example ([383](#)) – that affected the findings here. I also have no information on the timing of interventions such as the 999 call or initiation of CPR relative to the initial patient collapse.

The only randomised controlled trial (RCT) to date – in Stockholm (2012–2013) – failed to show a survival benefit in the use of a volunteer first-responder system ([162](#)). However, the primary outcome in that study was

bystander CPR provision, it was underpowered for outcome of survival to 30 days and it did not consider public-access AED use. Additionally, a Cochrane systematic review subsequently judged that the certainty of this finding was 'low' because of a high number of excluded cases and missing data ([159](#)).

Other observational studies have shown an improvement in survival to hospital discharge when a volunteer first-responder was activated via mobile phone (compared to a standard ambulance service response only) ([163,164](#)). A meta-analysis combining data from the RCT ([162](#)) and two of these observational studies ([163,164](#)) reported an overall OR for survival to hospital discharge (or at 30 days) of 1.51 (95% CI 1.24-1.84;  $p < 0.001$ ) ([386](#)).

Work in this chapter adds to the literature reporting that volunteer first-responders provide CPR and defibrillation on a number of occasions when they arrive on scene. In a study from the Netherlands, lay rescuers were the first to perform CPR for 25% (72/291) and connect an AED for 27% (78/291) of 291 OHCA cases where at least one rescuer attended ([164](#)). In the Stockholm RCT (2012–2013), bystander CPR rates were significantly higher in the group of OHCA patients for whom there was a volunteer first-response ([162](#)). This chapter reports that CPR and/or defibrillation was performed in more than half of cases where a GoodSAM responder reached the patient, although it is not clear if they were the first to do this. When GoodSAM responders did not perform CPR it is not always clear why, but possibilities include bystanders already performing CPR or GoodSAM responders making a judgement about the futility of initiating CPR.

What this study demonstrates in addition is that GoodSAM responders were often able to provide CPR and/or defibrillation, or other assistance, even when arriving after the ambulance service.

### **10.5.3 Strengths and limitations**

I could not determine an optimum GoodSAM alert distance threshold for either ambulance service area, so I did not proceed to examine this threshold for

more local areas (boroughs, counties or unitary authorities). There was local variation in alert acceptance rate but a detailed examination of the possible reasons for this was beyond the scope of this study. Different local areas may have marked differences in the proportions of GoodSAM responders that are there as residents or commuters, and the population and/or responder density will vary. Neighbourhood characteristics can have a substantial impact on OHCA outcome (75,80) and it may also be that the effect of a GoodSAM response is different in these different areas. Investigating what affects a GoodSAM responder's opportunity or motivation to respond in a particular geographical area is a potential area for further study.

One of the objectives in this chapter was to determine the proportion of GoodSAM alerts that resulted in a GoodSAM responder reaching the patient's side before the arrival of the ambulance service. I designed a questionnaire, delivered via Survey Monkey, with that in mind. It became apparent that it was often possible to determine whether a GoodSAM responder had arrived on scene and at the patient by examining their response to the post-event in-app feedback already in use. It was not always possible to determine if they had reached the patient before or after the ambulance, so combining the in-app data with questionnaire data created a number of 'unknown' responses re: time of arrival relative to the ambulance service.

I also attempted to determine whether a GoodSAM responder reaching the patient's side was associated with survival to hospital discharge following OHCA. Logistic regression models did not explain much of the variability in survival to hospital discharge but there were concerns with the models and data used for them.

In this chapter I relied on observational data, and the evidence thus produced would be considered at best low certainty according to the GRADE (Grading of Recommendations, Assessment, Development and Evaluations) framework (209). It is likely that there are other confounders that this study has not fully allowed for.

It was my intention to adhere to the rule of thumb of a minimum of ten outcome events per predictor variable (307) for the logistic regression model – here the outcome event of interest is the patients who actually survived to hospital discharge. However, restrictions in OHCA data submission due to COVID-19 ultimately meant that I had less data than anticipated with which to work. The use of 11 predictor variables in the London models for 93 surviving patients and 7 predictor variables in the East Midlands models for 34 surviving patients means that the logistic regression models probably include too many variables.

For ‘model 2’, those cases where it was not known whether a GoodSAM responder arrived before or after the ambulance service were *not* considered to have arrived before. Some of them undoubtedly would have done so and this may have affected the AOR calculations.

Further, in the EMAS dataset, I could only consider residential OHCA, and I could not reliably interpret who witnessed the OHCA or initiated CPR in a number of cases. EMS-witnessed OHCA was associated with increased survival in the LAS dataset. Systematic review and meta-analysis data suggest that EMS-witnessed OHCA (34,64) and bystander CPR (64) predict survival. The exclusion of non-residential OHCA and this other data substantially compromises the EMAS OHCA data and, in reality, means that one cannot draw any meaningful conclusions from it.

There is variability in how ‘daytime’ is defined with studies about OHCA outcomes, with studies dividing up the 24-hr day into two (387,388), three (383) or four (385) time periods of different length. One should also remember that comparisons made in GoodSAM alert acceptance rates and arrival at the patient’s side between day/night and weekday/weekend were unadjusted analyses.

This lack of standardisation makes direct comparison to other studies problematic. My decision to classify a 12hr day and night (which I made *before* any data analysis) is somewhat arbitrary, although using 0800-1959 for ‘day’

has been reported previously (387). There is precedent in the literature for classifying public holidays as weekends rather than weekday (383). However, I classified weekends as Saturday and Sunday, but others might think it reasonable to consider Friday 'night' (after 2000hrs in this study) or Monday 'night' (0000-0759) as the weekend too. Changing the thresholds for day/night and weekday/weekend potentially affects the outcome of analyses but this was not investigated here.

There were inconsistencies at times between data from different sources that I used in this chapter. This included contradictory information between the Survey Monkey questionnaire and the post-event in-app feedback. Neither was mandatory for the GoodSAM responder to complete, so I was able to spot contradictions only when both were completed. It was reasonable to give precedence to the in-app feedback as, after discussion with GoodSAM, we felt that this was most likely to have been filled out contemporaneously. The concern is that there were a number of other questionnaire or in-app feedback responses that were inaccurate representations of what actually happened and, because on these occasions there was no confirmation from a second source, there was no way to detect this. This could have been mitigated if the relevant questions in the questionnaire had been incorporated into the in-app feedback, but this was not something that GoodSAM could accommodate on this occasion.

On reviewing the EMAS data it became apparent that there were no EMS-witnessed OHCA's. My clinical experience told me this was unlikely and so I checked that there was no error in the data I had been given by the OHCAO registry. Registry personnel confirmed that this was how EMAS had submitted the data. It highlights the importance of carefully reviewing secondary data and 'sense-checking', but the potential for unrecognised errors remains.

There were inadequacies in the questionnaire design that could have been mitigated by testing or piloting. The failure to allow multiple responses to the assistance provided question (to allow people to record if they had performed CPR *and* defibrillation) was a clear error that I failed to spot despite reviewing

the final questionnaire in Survey Monkey. I underestimated how often people would put 'other' and so did not attempt to formally characterise this. A review of the free-text in the in-app feedback suggests that 'other' includes basic and more advanced airway interventions, patient moving and handling and help preparing equipment, although I did not formally investigate or analyse this.

Despite these problems this study has provided useful and novel descriptive information about how many GoodSAM responders reach the patient's side following alert acceptance, and the assistance that they provide.

#### **10.5.4 Clinical implications**

The work in this chapter provides insight, for the first time, into the actions that GoodSAM responders take once they accept an alert. This study demonstrates that GoodSAM responders can provide assistance even if they arrive after the ambulance service. Ultimately, however, I did not find evidence to confirm the work from **chapter 6** that the use of GoodSAM improves survival to hospital discharge in OHCA.

Early CPR and defibrillation improve survival to hospital discharge ([6,69,122](#)) and, as these are actions that GoodSAM responders can and are performing, there is a plausible mechanism by which the use of a volunteer first-responder system could improve survival to hospital discharge. GoodSAM, and other volunteer first-responder systems, are an increasing part of clinical practice for the management of OHCA. RCTs remain the most effective way to determine a causative link between an intervention and the outcome(s) of interest.

There were very few occasions where more than one GoodSAM responder accepted an alert: a finding also noted in **chapter 6**. As discussed in relation to AED use in **chapter 9**, many interventions to improve the effectiveness of the GoodSAM response may be contingent on having multiple responders to an incident. The work in this chapter reinforces the need for GoodSAM and its ambulance partners to consider effective means of increasing the number of responders on its platform.

In April 2018 GoodSAM introduced an app feature so that the audible alarm of an alert would still sound (if enabled by the user) even if the phone was on 'silent' mode. Despite this, around half of the alerts in this study period were 'not seen' by the GoodSAM responder. The reasons for this are not clear and investigating why this is still happening provides a potential means to improve alert acceptance rates.

There was no obvious relationship between a GoodSAM responder's distance from an incident and the likelihood of them accepting an alert. Following work in **chapter 6**, GoodSAM increased the alerting radius in London from 300m to up to 700m. This seems to have been justifiable, as a far higher number of alerts were accepted for only a small decrease in acceptance *rate*.

A substantial proportion of GoodSAM responders travelled by motor vehicle to the alert, in contravention of the expectation from GoodSAM ([298](#)). Indeed, this was the most common mode of travel in East Midlands. This may potentially increase the effective alerting radius in a number of regions of the UK (and worldwide) where GoodSAM is active. It makes the travel time estimates presented in this chapter (approx 100m/min) less useful. Further, the walking speed might be an underestimate, as a recent study suggested that the travelling speed of volunteers responding on foot to OHCA in Sweden was a median of 138m/min ([317](#)).

Alerts for OHCA were accepted more often compared to the study periods in **chapter 6** – LAS 11% vs 1.3% (2016–2017); EMAS 11% vs 5% (2018). There was manual correction of a substantial number of alert statuses in this study that did not occur for the previous work so a direct comparison is difficult. Nonetheless, even if these manual corrections were disregarded it does appear that a larger proportion of alerts for OHCA were accepted in 2019 compared to the previous study periods.

This chapter presents parallel results from two ambulance services. Differences in the study areas – including patient characteristics, and population and responder density – make direct comparison of the results

between the two areas unwise. The Utstein comparator group (bystander witnessed OHCA receiving CPR, with a shockable rhythm) can directly compare the effectiveness of different systems (9), but I have not done this here. To do so overestimates the utility of the GoodSAM app. At the time of the alert, the responder does not know the aetiology and initial cardiac rhythm, or even if the patient has actually sustained an OHCA. GoodSAM responders are deployed for all-cause OHCAs and so its influence on clinical outcomes should be judged in all-cause OHCAs.

### **10.5.5 Next steps**

I have disseminated this information to GoodSAM and ambulance service partners. There is an opportunity to review how and what information GoodSAM gathers in its post-event in-app feedback, and to incorporate the external questionnaire into this, to better characterise what interventions GoodSAM responders perform on scene. Given the number of times that the alert status was manually changed, there is also the opportunity to investigate why so many alerts are not 'accepted' in the app itself despite the responders actually going to the scene to provide assistance. Examining why so many alerts are still 'not seen' is another area for investigation.

GoodSAM and other volunteer first-responder systems are now embedded in clinical practice for the management of potential OHCAs in many countries. Conducting RCTs to effectively implement specific interventions at points along the journey from receipt of a GoodSAM alert to the arrival at the patient's side may be one means of improving clinical outcomes. In **chapter 9**, I have already described the development of potential interventions related to public-access AED use during an alert.

## **10.6 CONCLUSION**

GoodSAM responders accepted 23% alerts in London, and 29% in East Midlands. It was rare that more than one responder accepted an alert. Around half of alerts were still not seen. A high proportion of those responders who

did accept an alert reached the patient and provided assistance, even if the ambulance service arrived there first. Real-world travel distances for responders were substantially longer than straight-line estimates. However, I could identify no distance threshold using either estimate to predict whether or not a GoodSAM responder would accept an alert or get to the patient's side before the ambulance service.

I could provide no confirmatory evidence for a beneficial effect of a GoodSAM alert on survival to hospital discharge in OHCA. There were data quality and completeness issues, but it is likely that there are a number of factors affecting survival that have not been accounted for in the logistic regression modelling. RCTs examining specific interventions during a GoodSAM alert may represent the best opportunity to improve clinical outcomes for OHCA patients.

# CHAPTER 11

## Thesis Discussion

## 11.1 MAIN FINDINGS

The effect of the GoodSAM first-responder system on survival to hospital discharge in out-of-hospital cardiac arrest (OHCA) is not certain. Few OHCA trigger a GoodSAM alert, but when GoodSAM responders accept an alert many of them make it to the patient's side to provide assistance.

There are a number of barriers to public-access automated external defibrillator (AED) use for OHCA, by both bystanders in general and by GoodSAM responders. It is feasible to develop interventions guided by validated behavioural change models that aim to increase public-access AED retrieval during a GoodSAM alert.

I could not validate the finding in **chapter 6** that GoodSAM alert acceptance was associated with improved survival to hospital discharge in either London or East Midlands, albeit there were limits to the data analysis in **chapter 10**. Additionally (**chapter 10**), arriving at the patient before the ambulance service was not associated with survival to hospital discharge either.

A minority of GoodSAM alerts were for confirmed OHCA, and for a minority of OHCA was a GoodSAM responder alerted. There were noticeable differences between the number of OHCA where a GoodSAM responder was alerted in **chapter 6** (6.7% London, 22% East Midlands) and **chapter 10** (32% London, 33% East Midlands). The reasons for the differences were not explored, but in London this will reflect at least in part the increase in alerting radius from 300m to 400m (Tier 3 responders) or 700m (Tier 1 and 2 responders).

Alert acceptance rates for OHCA remain low but did increase in both ambulance services regions (London, 11% of total OHCA accepted (2019) vs 1.3% (2016–2017); East Midlands 11% (2019) vs 5% (2018)). Multiple acceptances for OHCA were very rare and, further, in the 2019 datasets (**chapter 10**) more than one GoodSAM responder arrived at the patient's side before the ambulance on only four occasions (London) and one occasion (East Midlands).

In **chapter 10** I was able to provide, for the first time, information about what GoodSAM responders do after accepting an alert. The majority (77% in London, 87% in East Midlands) reached the patient's side, many (39% London, 63% East Midlands) doing so before the ambulance. The majority provided some form of assistance (63% London, 79% East Midlands), including those who reached the patient after the ambulance service.

I have reported the potential for public-access AED use within the GoodSAM system. GoodSAM responders in the interview study (**chapter 8**) had concerns about locating AEDs and AED availability at the time of an OHCA. They were also concerned about taking extra time to retrieve an AED and the negative impact this might have on the patient, if other people were not already providing effective assistance. In **chapter 7** I reported that fewer than 10% OHCA occurred within 100m of a public-access AED known to either London Ambulance Service (LAS) or East Midlands Ambulance Service (EMAS). I was able to demonstrate that calculating real-world travel distances rather than straight-line distances substantially reduced this estimate. By calculating real-world travel distances, the identity of the nearest public-access AED changed – in both ambulance service regions – in 26% cases.

In **chapter 9**, for the first time in a volunteer first-responder system for OHCA, I used validated behavioural frameworks to first identify barriers to public-access AED use and then develop ten possible interventions to overcome these barriers. These interventions targeted a GoodSAM responder's capability (two interventions), opportunity (two interventions) and motivation (six interventions) to retrieve a public-access AED en-route to a potential OHCA.

## **11.2 COMPARISON WITH THE LITERATURE**

Work in **chapter 6** and **chapter 10** added to the limited outcome data about mobile-phone-activated volunteer first-responder systems. The only Randomised Controlled Trial (RCT) data (Stockholm 2013–2015) ([162](#)) did not show an improvement in survival to hospital discharge when a volunteer first-

responder was activated. This trial was powered only to the primary outcome of bystander cardiopulmonary resuscitation (CPR) rates rather than any survival outcome, and did not consider the use of public-access AEDs. In unadjusted analyses from that study, survival in the group for whom a volunteer first-response was made was 11.2% vs 8.6% for the control/standard ambulance response group (odds ratio (OR) 1.34, 95% CI 0.79-2.29;  $p=0.28$ ).

Other observational studies have reported benefit ([163,164](#)). A further study (South Korea) reported on the introduction of a volunteer first-responder system (in 2015) as part of a suite of measures to improve OHCA outcomes. It reported an adjusted odds ratio (AOR) of 1.84 (95% CI 1.29-2.63) for survival to hospital discharge and 2.31 (95% CI 1.44-3.70) for survival with favourable neurological outcome for the intervention bundle in a before-and-after study ([166](#)). The contribution of the volunteer first-responder system to this finding was not clear.

Observational studies are subject to unrecognised confounders, and may be limited by the appropriateness of variables entered in the logistic regression modelling. The observational study by Pijls et al ([164](#)) (Limburg, Netherlands, 2012–2014) reported a survival to hospital discharge benefit if at least one volunteer first-responder was activated. Ventricular fibrillation or ventricular tachycardia (VF/VT) rates were higher in the group receiving a volunteer first-response, but this variable was not included in logistic regression modelling. Similarly, in **chapter 10** of this thesis, there were limitations in the logistic regression models. This included the exclusion of residential OHCA, ambulance-serviced witnessed status and who performed CPR for EMAS data, and an ‘overfitting’ of both LAS and EMAS models because there may have been too many predictor variables for the limited number of outcome events (survival to hospital discharge) ([307](#)).

In a study by Stroop et al. ([163](#)) (Gütersloh, Germany, 2013–2017), outcomes were better in the group of patients where CPR *was initiated* by a volunteer first-responder (compared to the ambulance service or another bystander).

This overestimates the utility of the volunteer first-responder system as, clearly, only a proportion of those activated will arrive at the patient's side in time to be the first to perform CPR.

A 2020 meta-analysis pooled data from the RCT by Ringer et al ([162](#)) and the observational studies by Pijls et al ([164](#)) and Lee et al ([166](#)). It reported survival to hospital discharge of 14.4% (327/2273) when a volunteer first-responder was activated via mobile phone vs 9.4% (184/1955) in the control/standard response group (OR 1.51, 95% CI 1.24-1.84;  $p < 0.001$ ) ([386](#)).

A 2010 systematic review and meta-analysis (1984–2008) reported that ambulance service- or bystander-witnessed OHCA, bystander CPR, and VF/VT as initial cardiac rhythm all predicted increased survival to hospital discharge ([34](#)). In an English dataset (using 2014 OHCA data and then validated on 2015 data) age, gender, aetiology, bystander-witnessed OHCA, bystander CPR and VF/VT formed an effective prediction model for survival to hospital discharge ([33](#)).

In this PhD, factors that were consistently associated with increased survival to hospital discharge (in data from both **chapter 6** and **chapter 10**) were age (increased age = lower survival), VF/VT or PEA compared to asystole (apart from EMAS data in **chapter 10** when only VF/VT was associated), and ambulance service- or bystander-witnessed OHCA compared to unwitnessed. Other factors – public location OHCA, ambulance service response time, or weekday vs weekend OHCA (in **chapter 10** only) – were sometimes associated and sometimes not associated with improved survival to hospital discharge. Bystander CPR and bystander AED use, where reported, were not associated with survival to hospital discharge in logistic regression models. This is contrary to the generally accepted evidence that both bystander CPR – albeit limited to those with shockable cardiac rhythms ([64](#)) – and bystander AED use ([69](#)) improve survival to hospital discharge. I was unable to determine how soon after a patient's collapse bystander CPR/AED was performed, which is an important determinant of their effect. I could also not distinguish between an AED that was attached and an AED that delivered a shock.

Few GoodSAM alerts resulted in (at least one) responder accepting, but other researchers have reported higher acceptance rates: a Netherlands text-message alert system (2010) reported 27% cases where at least one responder accepted (170); in the USA (2012–2014) 23% accepted an alert from the Pulsepoint mobile-phone volunteer first-responder app (167); in Stockholm, Sweden (2013–2015), 65% alerts resulted in at least one responder accepting, 59% resulted in at least one responder arriving on scene, with a responder first on scene for 23% alerts; in Odense, Denmark (2012–2017) a volunteer first-responder arrived on the scene before the ambulance in 85% of cases (175).

There has been no direct comparison between systems to investigate if there are differences in responder attitudes in different countries or regions. Much of this difference may represent that there were more responders accepting per alert (168,170), and so the chance of at least one responder having accepted any given alert is higher. Other systems have reported that volunteer first-responders provide CPR (162,164,167,171), attach AEDs (168,171,389) and otherwise help the ambulance service (170), although none explicitly consider the help provided by volunteer first-responders who only arrive at the patient after the ambulance service.

Currently, it is not clear what impact public-access AED use by volunteer first-responders will have on patient outcomes in OHCA. In the capital region of Denmark (2017–2018), observational data showed that defibrillation by any bystander was greater than three times more likely if a volunteer first-responder arrived at an OHCA patient before the ambulance service (OR 3.73, 95% CI 2.04-6.84;  $p < 0.001$ ). However, patient outcome data were not reported (355). In Denmark, survival from public-location OHCA showed an inverse relationship to the distance from the nearest public-access AED (280).

In this PhD, fewer than one in ten OHCA in London and East Midlands occurred within 100m of an AED, and this estimate dropped still further when considering real-world travel distance (**chapter 7**). The work in **chapter 8** reported on the many other challenges that exist, other than AED availability,

in getting a public-access AED to a patient as part of a GoodSAM alert. Volunteer first-responders who divert to retrieve a public-access AED are likely to travel substantially further (171) and take substantially longer to reach the patient (173). These are all potential barriers to early defibrillation and improved survival.

The Scandinavian AED and Mobile Bystander Activation (SAMBA) RCT is still recruiting in Denmark and Sweden, randomising users of the Hearrunner volunteer first-responder app to: all responders instructed to go straight to the patient to start CPR (control), or a proportion of responders (if more than one available) asked to retrieve an AED first (intervention). It may provide better evidence for the impact of AED use in a volunteer first-responder system, but even this trial is powered only for its primary endpoint of AED attachment before the arrival of the ambulance service. It will report on difference in 30-day survival as a secondary outcome (183).

Researchers in Denmark interviewed OHCA bystanders and performed an in-depth and well-described thematic analysis of facilitators to CPR and AED use in OHCA (268). The interview study in **chapter 8** reported on several of the same facilitators among 30 GoodSAM responders, namely: the beneficial effect of training, knowledge that intervening may improve survival and a perceived moral obligation to help. However, work in this PhD to identify barriers *and develop interventions to overcome them* has not appeared elsewhere in the published literature.

In this PhD I demonstrated that straight-line travel estimates – whether considering public-access AED retrieval by any bystander (**chapter 7**), or travel distance by a GoodSAM responder accepting an alert (**chapter 10**) – are substantially shorter than real-world travel distances. Much of the literature about mobile-phone-activated volunteer first-responders describes activation within a certain radius (162,164,167,168,171,174,175), but there is now an increasing recognition of how the discrepancy between straight-line and real-world travel distance might affect volunteer first-responders (171,173) and estimates of public-access AED coverage for OHCA (276-278).

Travel *time* is another important consideration. If volunteer first-responders are responding by motor vehicle – as I found many were in **chapter 10**, and as reported in a volunteer first-responder system in the Ticino region of Switzerland (173) – the distance they can travel in a given time period will be greater.

### **11.3 STRENGTHS AND LIMITATIONS**

The work evaluating the use of GoodSAM includes data from thousands of OHCA and GoodSAM alerts across **chapter 6** and **chapter 10**. Nevertheless, actual numbers of ‘accepted’ GoodSAM alerts for OHCA were low, and this is reflected in the wide confidence intervals for the effect size estimates for the outcome measure. This imprecision, seasonal differences in OHCA incidence and outcome (383,390,391), the potential for unrecognised confounders, and previously mentioned concerns re: the logistic regression models in **chapter 10** are all potential reasons why I could not confirm the findings from **chapter 6**. I cannot confidently report whether or not the acceptance of a GoodSAM alert is associated with improved survival to hospital discharge.

I chose survival to hospital discharge as the main outcome measure in both **chapter 6** and **chapter 10** as it is important to clinicians, OHCA patients and their families (13). The data were not available to consider the effect of GoodSAM on survival with good neurological outcome or longer-term outcomes following OHCA. I considered the effect of GoodSAM on *all cause* OHCA, as this is the most appropriate indicator of the overall utility of a system in which – at the point it is activated – little is known about the aetiology of an OHCA. This approach – rather than analysing only OHCA from the Utstein comparator group (bystander-witnessed OHCA who received CPR and had a shockable rhythm, and for whom the ambulance service attempted resuscitation) (9) – makes a direct comparison between LAS and EMAS inappropriate. However, there is nothing to stop representatives of both services discussing my results and sharing examples of good practice. Instead, here, the reader must consider the work in these chapters as two parallel evaluations, one for each ambulance service region.

The evaluation work in both **chapter 6** and **chapter 10** about the effect of GoodSAM on survival to hospital discharge was observational in nature. Such studies usually represent low- or very low quality evidence: there is a high likelihood that further research will change how certain we are of any reported effect (209). The work presented here would be likely be considered at least at ‘serious’ risk of bias (on a scale of low, moderate, serious and critical) using the ROBINS-I (The Risk Of Bias In Non-randomized Studies – of Interventions) assessment tool, which is recognised by Cochrane (115). I have not performed a formal critical appraisal, and would have a clear conflict of interest if I were to do so, but areas of concern for a higher risk of bias were:

- Confounding – the logistic regression models explained no more than 40% of the variance in survival to hospital discharge. There were some data that were not available for both ambulance services in all cases, and there were probably other confounders that I could not account for. These may include, but not be limited to: OHCA aetiology; time from collapse to the onset of bystander interventions; and quality of interventions (by either GoodSAM responder or other bystander)
- Selection bias – I included all OHCAs made available to me from the Out of Hospital Cardiac Arrest Outcomes (OHCAO) registry in my analyses. However, it is possible that ambulance services did not report all eligible OHCAs to the OHCAO registry. Cases should be reported if resuscitation was initiated or continued by the ambulance service: the threshold for deciding not to initiate or continue CPR could potentially differ between ambulance services. EMAS data from **chapter 10** did not include non-residential OHCAs
- Misclassification bias – I have discussed problems with data acquisition in the relevant chapters. There was no way to link OHCAs in the OHCAO database with GoodSAM cases by a common identifier, and I had to match these manually by searching for a common date, time and incident location. **Chapter 10** revealed discrepancies between the alert status (whether the GoodSAM responder had indicated with a button press on their mobile phone whether they ‘accepted’ or ‘rejected’ an

alert) and post-event feedback describing interventions that they had performed, and I made some manual adjustments. It is inconceivable that I managed this task without a single error

- Missing data – there was little missing data overall, with logistic regression models including between 88-97% of cases across both **chapter 6** and **chapter 10**. The exclusion of non-residential OHCAs for EMAS in **chapter 10** increases the bias for this dataset: bystander intervention- and survival rates are usually higher in public-location OHCAs (1). Reporting on survival to hospital discharge requires linkage between pre-hospital and in-hospital data. The NHS number is a key means of doing this and, as this may not be available in the pre-hospital setting, it may be more likely that the missing data represented those that did not survive to hospital admission (392)

The reliability of quantitative data from secondary sources was an important issue for consideration at several points in this PhD. In **chapter 10**, there were occasional discrepancies between data collected in the post-event Survey Monkey questionnaire, and that collected via the existing in-app feedback mechanism. Given that post-event feedback often contradicted the alert status information ('accepted' or 'rejected' alerts requiring a button press that was evidently not always done), GoodSAM may wish in particular to consider adding a confirmation of whether people travelled to scene +/- reached the scene +/- reached the patient.

Streamlining this data collection process and collecting GoodSAM data from just one source (i.e. integrating the Survey Monkey questions with the post-event feedback) would improve confidence in the data and is something GoodSAM should consider for future projects. GoodSAM responders themselves may have important insights about the problems regarding the post-event feedback mechanisms. This was briefly explored in the interview study (**chapter 8**), but was not the main focus.

The nature of a PhD project means that routine, independent checking of data input is not practical. It is, though, clearly one way to improve confidence in the accuracy of data analysis, particularly when making manual changes to the data. The sensitive (and sometimes proprietary) nature of the data I collected means making raw data available for public scrutiny or as part of a peer-reviewed publication is problematic, and so independent verification within a project study team would have been that much more useful.

Reporting the proximity of public-access AEDs to OHCA was limited by including only those AEDs known to the ambulance services. This will be an underestimation of the total number of AEDs available (136,249), and those not registered with the ambulance service can still be used if bystanders themselves know of their location. Roll-out of a new national database of public-access AEDs ('The Circuit') (109) may help address this issue somewhat. Nevertheless, in this project I have demonstrated a feasible method of measuring real-world travel distances (in both **chapter 7** and **chapter 10**). This information could be used to model accurate travel time estimates by local ambulance services and GoodSAM when determining how best to dispatch bystanders or first-responders to public-access AEDs.

The interview study (**chapter 8**) demonstrated that remote interviewing – including delivered of patient information, consent-taking and recording – is feasible. Participants may provide more complete and honest answers to sensitive questions by remote interviewing (327), and researchers in Denmark used telephone interviews for lay bystanders to real OHCA (2012–2017) to gather useful information about a recent sensitive event in a private and secure fashion (268). This is even more relevant to the world in 2020 and beyond: there has been a proliferation of remote video-conferencing since the onset of the COVID-19 pandemic, and there is no reason why researchers shouldn't consider such techniques for interview studies.

A major strength of this PhD is the first documented use of an integrated, theoretically-informed approach from data collection to the development of a behavioural change intervention for volunteer first-responder systems

(**chapter 8** and **chapter 9**). There may be differences in other systems regarding volunteer first-responders' capability (e.g. the level of training required for registration), opportunity (e.g. number, placement and accessibility of AEDs, population density and number of responders), and motivation (e.g. legal issues surrounding AED use, ambulance response time, travel times and distances) to use a public-access AED that affect results there. However, I have presented a comprehensive and integrated framework that can be transferred to these systems.

#### **11.4 CLINICAL IMPLICATIONS**

It is my overall opinion that the evidence available does not yet clearly support the hypothesis that mobile-phone-activated volunteer first-responder systems improve survival to hospital discharge in OHCA. As more information becomes available, it should be subject to meta-analysis and critical appraisal using recognised tools (such as Cochrane Risk of Bias Tool for RCTs (393) and ROBINS-I for observational studies (115)) to better quantify whether or not there is likely to be an effect, and how certain of that effect we can be (209).

This PhD provided snapshots of an evolving system, but may help GoodSAM and local ambulance services improve how they use the app in OHCA. Early provision of CPR (64) and defibrillation (69) improve survival to hospital discharge, so it is entirely reasonable to hypothesise that a volunteer first-responder system that achieves this would itself improve survival. If we do not see such an improvement we must accept: a) bystander CPR and AED use don't actually improve survival, despite the weight of evidence supporting it; b) the implementation of the intervention (here, bystander CPR and AED use), rather than the intervention itself, is flawed; or c) there are other factors specific to a volunteer first-responder system that act against the beneficial effect of CPR and AED use, such as an ability to get responders to the scene quickly enough for CPR or AED use to impact survival.

Of these, b) and/or c) are by far the most likely. A high-quality, large-scale RCT evaluating a volunteer first-responder system would help to answer these

questions. The 2.6% absolute survival improvement in the Stockholm RCT (2013–2015) ([162](#)) was non-significant but the trial was underpowered for this outcome, further supporting the call for a larger trial.

Whether or not equipoise for such an RCT exists is uncertain. A second-best option would be well-conducted RCTs within systems to improve the timely delivery of interventions associated with important clinical outcomes. This PhD has demonstrated a means to develop interventions for evaluation in such circumstances. Indeed, qualitative research has a role throughout RCTs, helping us to understand the *impact* of the intervention(s) on patients and the GoodSAM responders themselves, their experiences with the intervention, their thoughts about what affects implementation of the intervention, and how barriers to implementation might be overcome ([394](#)). It is important in any RCT that any effect that we do (or do not) see is due to the impact of the intervention itself, and not because of poor or inconsistent implementation.

For this PhD, I specifically considered means of increasing public-access AED use during a GoodSAM alert. Deciding whether or not to retrieve an AED is difficult because the correct strategy (collect a public-access AED first or go directly to the patient) is dependent on a number of factors. Some of these – for example: OHCA aetiology, time since collapse, patient comorbidities – may affect the likelihood of successful defibrillation, but they are unknown to the GoodSAM responder making a time-critical decision at the time of an alert. There are no validated prediction models to determine likelihood of VF/VT at a particular time point after OHCA onset.

It became evident that many potential interventions designed to increase public-access AED retrieval by GoodSAM responders would only work if multiple responders accepted an alert on a regular basis. For example, an important motivator for public-access AED retrieval would be the knowledge that someone else was already on scene performing CPR. With multiple responders, some could then be sent directly to the patient with others being sent to retrieve an AED, as happens in the similar Hearrunner app system in Copenhagen ([355](#)).

Work in **chapter 6** and **chapter 10** complement the interview study and intervention development work in reporting that multiple acceptances for an alert are a rarity in the GoodSAM system. Until this changes, it will be difficult for many of the proposed interventions to increase public-access AED use. Increasing the number of responders registered with GoodSAM is therefore a key challenge to address and overcome. Any interventions that researchers consider should be developed with this in mind.

GoodSAM could potentially increase its number of registered users by increased or more focused advertising to both healthcare and lay groups, and/or relaxing its requirement for CPR certification for registration. Other first-responder systems – such as ‘Hearrunner’ (personal communication, F Lippert) and ‘myResponder’ in Singapore (<https://www.scdf.gov.sg/home/community-volunteers/mobile-applications>) – do not require responders to have CPR/AED certification. GoodSAM itself does not require responders in Victoria (Australia) and across New Zealand to have formal CPR certification, although they ask responders to keep their knowledge current (174).

Removing the need for CPR certification in the UK might change the skill mix and capability across the whole GoodSAM responder population. Subsequently, behavioural characteristics of the responder group and targets for behaviour change might be different to those identified in this PhD. The motivation to respond may be less in a population that has a higher proportion of non-CPR trained responders. A study from Victoria (2015–2017) reported that non-traumatic OHCA patients who received bystander CPR from someone with healthcare training were more likely to survive to hospital discharge (AOR 1.47, 95% CI 1.09-2.00;  $p=0.01$ ) (395). We need to research how best to balance the increased opportunity for an OHCA patient to receive a volunteer first-response with a potentially reduced responder motivation to respond and/or capability to perform effective CPR and use an AED.

I was not able to determine an optimum response radius for the GoodSAM system in London or East Midlands. If the radius is too small then the number of OHCA patients benefitting from a volunteer first-response will be small. If it

is too large then there will be a large proportion of cases where responders may make substantial efforts to reach a patient but are unable to provide meaningful assistance in a timely manner. Repeated instances of this will likely impact upon future motivation to respond. In London, I demonstrated that acceptance *rate* changed little with an increase in response radius from 300m (**chapter 6**) to 400m/700m (**chapter 10**) and this, although indirect, is the best indicator I can give from this PhD that the new response radius is acceptable to GoodSAM responders in London.

GoodSAM is being used in ways not intended when it was first launched. A number of responders attend using motor vehicles, and in many cases responders have provided direct assistance when arriving after the ambulance service. Indications from the interview study (**chapter 8**) suggest that the nature of this interaction is informal and unpredictable at times, and carries potential clinical governance concerns for ambulance services. GoodSAM responders are also finding themselves in non-OHCA situations and remaining on scene to provide help or reassurance. The app is being used for advanced planning, with people identifying the location and accessibility times of AEDs at times other than when accepting an alert.

GoodSAM, and other volunteer first-responder systems, are only one possible way to improve OHCA survival. Any evidence-based intervention – properly implemented and integrated into a comprehensive system of OHCA care – that improves OHCA recognition or increases the prompt delivery of CPR or AED use may help achieve this goal (89-92).

Education of the wider population about the importance of early intervention is likely to be an important part of improving OHCA survival. Increasing rates of CPR/AED training among the population may even mitigate the effect of opening GoodSAM up to those without formal certification. The global ‘Restart a Heart Day’ initiative (106) aims to train and provide as many people as possible with CPR/AED skills on or around October 16<sup>th</sup> each year. In 2019, around 291,000 people received training in the UK (105). Training in CPR was

made part of the school curriculum in England in September 2020, and will also be implemented in all areas of Scotland (107).

When specifically considering AED use, there are a number of factors that might affect successful public-access AED retrieval during an alert that GoodSAM, or the GoodSAM responder, cannot directly influence. I have not considered these in detail in this PhD, but they may include: recommending (396) or mandating that public-access AEDs be kept in unlocked cabinets; providing low-cost, personal AEDs to volunteer first-responders; and investigating other methods to dispatch public-access AEDs to the scene of an OHCA. Other means of getting a public-access AED to the scene include using community responders specifically tasked to respond with an AED (376), taxis (397), or drones (288-290). Determining the optimum density (389) or location of public-access AEDs (179) to most effectively provide coverage for OHCA is another strategy. A National Institute for Health Research (NIHR) funded project is currently working to optimise the placement of public-access AEDs in England (398). Patient outcome data are lacking for any of these schemes.

The importance of using real-world travel distance should become more relevant as ambulance service dispatch systems across the UK strive to strengthen mechanisms that assist bystander retrieval of a public-access AED during an OHCA. If the national AED database (109) is comprehensive it will provide more opportunity than ever before for a bystander to find and use a public-access AED. We must ensure that we make the best use of it by correctly identifying the closest available AED, using distance and time estimates based on the real-world route that a bystander would most likely use.

The long-term effect of the COVID-19 pandemic on bystander interventions for OHCA remains to be seen. A systematic review published in October 2020 identified two studies reporting that bystander-initiated CPR rates had fallen and three reporting no difference (71). Pooled results in another systematic review and meta-analysis from October 2020 suggest no overall change in

bystander CPR rates, but a decrease in bystander AED use (72). There are international guidelines aimed at reducing the risk for rescuers during resuscitation attempts (399), although the precise risk of virus transmission during CPR and defibrillation is not entirely clear (400). Any intervention (within or without a volunteer first-responder system) designed to improve important OHCA outcomes by means of increasing CPR and AED use must engage a population whose attitudes to resuscitation may have been substantially altered in the wake of COVID-19.

### 11.5 NEXT STEPS

The GoodSAM first-responder app is now used in most ambulance trusts across the UK. A key priority is increasing numbers of responders on the platform so that a greater proportion of OHCA have a GoodSAM responder 'accept' an alert, and so more OHCA have multiple alert acceptances. Whether or not this is done by increasing publicity and visibility around the app or by increasing the potential pool of responders by changing the responder eligibility rules is something for GoodSAM and local ambulance services to discuss.

I have developed a list of interventions to increase public-access AED use. I will liaise with GoodSAM and ambulance service partners about which of these to test further, and how. The behavioural change process that I described in **chapter 8** and **chapter 9** concerns the decision to retrieve a public-access AED during an alert, but this decision is intricately related to the decision to accept an alert. I propose using a similar process to the one reported in those chapters to develop interventions to improve alert acceptance.

There are a number of 'quality improvement' activities that GoodSAM may consider following work in this PhD. These include the ongoing problem of not hearing alerts, and suboptimal data collection processes on occasion. GoodSAM now operates a number of other ventures alongside its OHCA response platform, including on-scene video streaming to aid ambulance (301) and other emergency services (401) in their dispatch decisions, and the NHS

Volunteer Responders programme that has supported the NHS during the COVID-19 pandemic (302). It will be for them to determine how they wish to prioritise their competing interests, and for OHCA researchers and local ambulance services to help them in those activities that might improve OHCA outcomes.

There is also the opportunity to liaise with international partners who operate similar mobile-phone-activated volunteer first-responder systems. At least, the work in this PhD has provided a robust template for others to develop behaviourally-informed interventions to test in their own systems.

Survival with favourable neurological outcome and longer-term survival and morbidity are other important clinical outcomes following OHCA (13). At the moment there is no easy way to collect this information on a large scale in the UK. If the OHCAO registry develops in such a way that this data are routinely available, research projects using this data should consider the effect of any intervention on these outcomes too.

# CHAPTER 12

## Thesis Conclusion

The effect of the GoodSAM first-responder system on survival to hospital discharge in out-of-hospital cardiac arrest (OHCA) is uncertain. In general, high-quality evidence for the benefit of mobile-phone-activated volunteer first-responders in OHCA is lacking. It is feasible that such an approach would work if it can deliver timely cardiopulmonary resuscitation (CPR) and Automated External Defibrillator (AED) use.

Few alerts for OHCA are accepted by GoodSAM responders, but a high proportion of those that do accept reach the scene. They often provide CPR/AED or other interventions, even if arriving after the ambulance service.

When alerting first-responders to an OHCA or sending first-responders or bystanders to locate and retrieve a public-access AED, ambulance services and GoodSAM should ensure that travel distance and/or time estimates are made using real-world travel routes rather than straight-line distance estimates.

There is an urgent need for high-quality, large-scale randomised controlled trials (RCTs) to confirm or refute the benefit of volunteer first-responder systems described in some existing studies. If there is not clinical equipoise for this, RCTs of interventions to improve timely CPR and AED use *within* a system represent the best chance to optimise that system. It is feasible to develop interventions for RCT evaluation using theoretically-informed behavioural change techniques. This approach may be crucial for the successful implementation of the interventions one wishes to evaluate.

Mobile-phone-activated volunteer first-responders have the potential to improve OHCA survival. They are only one of several methods to strengthen the community response to OHCA and improve clinically important outcomes.

# CHAPTER 13

## References

1. Hawkes C, Booth S, Ji C, et al. Epidemiology and outcomes from out-of-hospital cardiac arrests in England. *Resuscitation* 2017;110:133-40.
2. Berdowski J, Berg RA, Tijssen JGP, et al. Global incidences of out-of-hospital cardiac arrest and survival rates: Systematic review of 67 prospective studies. *Resuscitation* 2010;81:1479-87.
3. Grasner JT, Lefering R, Koster RW, et al. EuReCa ONE-27 Nations, ONE Europe, ONE Registry: A prospective one month analysis of out-of-hospital cardiac arrest outcomes in 27 countries in Europe. *Resuscitation* 2016;105:188-95.
4. Ong ME, Shin SD, De Souza NN, et al. Outcomes for out-of-hospital cardiac arrests across 7 countries in Asia: The Pan Asian Resuscitation Outcomes Study (PAROS). *Resuscitation* 2015;96:100-8.
5. Yan S, Gan Y, Jiang N, et al. The global survival rate among adult out-of-hospital cardiac arrest patients who received cardiopulmonary resuscitation: a systematic review and meta-analysis. *Crit Care* 2020;24:61.
6. Perkins GD, Handley AJ, Koster RW, et al. European Resuscitation Council Guidelines for Resuscitation 2015: Section 2. Adult basic life support and automated external defibrillation. *Resuscitation* 2015;95:81-99.
7. Nishiyama C, Brown SP, May S, et al. Apples to apples or apples to oranges? International variation in reporting of process and outcome of care for out-of-hospital cardiac arrest. *Resuscitation* 2014;85:1599-609.
8. Wong CX, Brown A, Lau DH, et al. Epidemiology of Sudden Cardiac Death: Global and Regional Perspectives. *Heart Lung Circ* 2019;28:6-14.
9. Perkins GD, Jacobs IG, Nadkarni VM, et al. Cardiac Arrest and Cardiopulmonary Resuscitation Outcome Reports: Update of the Utstein Resuscitation Registry Templates for Out-of-Hospital Cardiac Arrest: A Statement for Healthcare Professionals From a Task Force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian and New Zealand Council on Resuscitation, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa, Resuscitation Council of Asia); and the American Heart Association Emergency Cardiovascular Care Committee and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. *Resuscitation* 2015;96:328-40.
10. Jennett B, Bond M. Assessment of outcome after severe brain damage. *Lancet* 1975;1(7905):480-4.
11. van Swieten JC, Koudstaal PJ, Visser MC, et al. Interobserver agreement for the assessment of handicap in stroke patients. *Stroke* 1988;19:604-7.
12. OHCAO Registry (2019). Out-of-Hospital Cardiac Arrest Outcomes Registry Epidemiology Report, 2018. Available from: [https://warwick.ac.uk/fac/sci/med/research/ctu/trials/ohcao/publications/epidemiologyreports/ohcao\\_epidemiology\\_report\\_2018\\_published.pdf](https://warwick.ac.uk/fac/sci/med/research/ctu/trials/ohcao/publications/epidemiologyreports/ohcao_epidemiology_report_2018_published.pdf) [last accessed 19th November 2020].
13. Haywood K, Whitehead L, Nadkarni VM, et al. COSCA (Core Outcome Set for Cardiac Arrest) in Adults: An Advisory Statement From the International Liaison Committee on Resuscitation. *Resuscitation* 2018;127:147-63.
14. Grasner JT, Wnent J, Herlitz J, et al. Survival after out-of-hospital cardiac arrest in Europe - Results of the EuReCa TWO study. *Resuscitation* 2020;148:218-26.
15. Vellano K, Crouch A, Rajdev M, et al. (2015). Cardiac Arrest Registry to Enhance Survival (CARES) Report on the Public Health Burden of Out-of-Hospital Cardiac Arrest. Available from: <https://mycares.net/sitepages/uploads/2015/CARES%20IOM%20Formatted.pdf> [last accessed 19th November 2020].
16. Kiguchi T, Kiyohara K, Kitamura T, et al. Public-Access Defibrillation and Survival of Out-of-Hospital Cardiac Arrest in Public vs. Residential Locations in Japan. *Circ J* 2019;83:1682-88.
17. Chan PS, McNally B, Tang F, et al. Recent Trends in Survival from Out-of-Hospital Cardiac Arrest in the United States. *Circulation* 2014;130:1876-82.
18. Dicker B, Davey P, Smith T, et al. Incidence and outcomes of out-of-hospital cardiac arrest: A New Zealand perspective. *Emerg Med Australas* 2018;30:662-71.
19. Malta Hansen C, Kragholm K, Dupre ME, et al. Association of Bystander and First-Responder Efforts and Outcomes According to Sex: Results From the North Carolina

- HeartRescue Statewide Quality Improvement Initiative. *J Am Heart Assoc* 2018;7:e009873.
20. Holmberg M, Holmberg S, Herlitz J. The problem of out-of-hospital cardiac-arrest prevalence of sudden death in Europe today. *Am J Cardiol* 1999;83(5, Suppl 2):88D-90D.
  21. Kiguchi T, Okubo M, Nishiyama C, et al. Out-of-hospital cardiac arrest across the World: First report from the International Liaison Committee on Resuscitation (ILCOR). *Resuscitation* 2020;152:39-49.
  22. NHS England (2020). Ambulance Quality Indicators Data 2019-20. Clinical Outcome Spreadsheets. Available from: <https://www.england.nhs.uk/statistics/statistical-work-areas/ambulance-quality-indicators/ambulance-quality-indicators-data-2019-20/> [last accessed 19th November 2020].
  23. Okubo M, Schmicker RH, Wallace DJ, et al. Variation in Survival After Out-of-Hospital Cardiac Arrest Between Emergency Medical Services Agencies. *JAMA Cardiol* 2018;3:989-99.
  24. Masterson S, Cullinan J, McNally B, et al. Out-of-hospital cardiac arrest attended by ambulance services in Ireland: first 2 years' results from a nationwide registry. *Emerg Med J* 2016;33:776-81.
  25. Dicker B, Oliver V, Tunnage B. Out of Hospital Cardiac Arrest Registry Annual Report 2017/18. Wellington, New Zealand: St John Ambulance, November 2018.
  26. Benjamin E, Muntner P, Alonso A, et al. Heart Disease and Stroke Statistics—2019 Update: Chapter 17. *Circulation* 2019;139:e377-e400.
  27. Andrew E, Nehme Z, Wolfe R, et al. Long-term survival following out-of-hospital cardiac arrest. *Heart* 2017;103:1104-10.
  28. Kragholm K, Wissenberg M, Mortensen RN, et al. Return to Work in Out-of-Hospital Cardiac Arrest Survivors: A Nationwide Register-Based Follow-Up Study. *Circulation* 2015;131:1682-90.
  29. Tiainen M, Vaahersalo J, Skrifvars MB, et al. Surviving out-of-hospital cardiac arrest: The neurological and functional outcome and health-related quality of life one year later. *Resuscitation* 2018;129:19-23.
  30. Geri G, Dumas F, Bonnetain F, et al. Predictors of long-term functional outcome and health-related quality of life after out-of-hospital cardiac arrest. *Resuscitation* 2017;113:77-82.
  31. Bohm M, Lilja G, Finnbogadottir H, et al. Detailed analysis of health-related quality of life after out-of-hospital cardiac arrest. *Resuscitation* 2019;135:197-204.
  32. Perkins GD, Travers AH, Berg RA, et al. Part 3: Adult basic life support and automated external defibrillation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. *Resuscitation* 2015;95:e43-69.
  33. Ji C, Brown TP, Booth SJ, et al. Risk Prediction Models for Out-of-Hospital Cardiac Arrest Outcomes in England. *Eur Heart J Qual Care Clin Outcomes* 2020 [E-pub ahead of print]
  34. Sasson C, Rogers MAM, Dahl J, et al. Predictors of Survival From Out-of-Hospital Cardiac Arrest A Systematic Review and Meta-Analysis. *Circ Cardiovasc Qual Outcomes* 2010;3:63-81.
  35. Deakin CD. The Chain of Survival: Not all links are equal. *Resuscitation* 2018;126:80-2
  36. Bohm K, Kurland L. The accuracy of medical dispatch - a systematic review. *Scand J Trauma Resusc Emerg Med* 2018;26:94.
  37. Deakin CD, England S, Diffey D. Ambulance telephone triage using 'NHS Pathways' to identify adult cardiac arrest. *Heart* 2017;103:738-44.
  38. Vaillancourt C, Charette M, Kasaboski A, et al. Cardiac arrest diagnostic accuracy of 9-1-1 dispatchers: a prospective multi-center study. *Resuscitation* 2015;90:116-20.
  39. Viereck S, Moller TP, Rothman JP, et al. Recognition of out-of-hospital cardiac arrest during emergency calls - a systematic review of observational studies. *Scand J Trauma Resusc Emerg Med* 2017;25:9.
  40. NHS England (2018). Ambulance Response Programme Review. Available from: <https://www.england.nhs.uk/wp-content/uploads/2018/10/ambulance-response-programme-review.pdf> [last accessed 19th November 2020].
  41. Cairns KJ, Hamilton AJ, Marshall AH, et al. The obstacles to maximising the impact of public access defibrillation: an assessment of the dispatch mechanism for out-of-hospital cardiac arrest. *Heart* 2008;94:349-53.

42. Deakin CD, England S, Diffey D, et al. Can ambulance telephone triage using NHS Pathways accurately identify paediatric cardiac arrest? *Resuscitation* 2017;116:109-12.
43. Fukushima H, Panczyk M, Hu C, et al. Description of Abnormal Breathing Is Associated With Improved Outcomes and Delayed Telephone Cardiopulmonary Resuscitation Instructions. *J Am Heart Assoc* 2017;6:e005058
44. Riou M, Ball S, Williams TA, et al. 'She's sort of breathing': What linguistic factors determine call-taker recognition of agonal breathing in emergency calls for cardiac arrest? *Resuscitation* 2018;122:92-98.
45. Alfsen D, Moller TP, Egerod I, et al. Barriers to recognition of out-of-hospital cardiac arrest during emergency medical calls: a qualitative inductive thematic analysis. *Scand J Trauma Resusc Emerg Med* 2015;23:70.
46. Chien CY, Chien WC, Tsai LH, et al. Impact of the caller's emotional state and cooperation on out-of-hospital cardiac arrest recognition and dispatcher-assisted cardiopulmonary resuscitation. *Emerg Med J* 2019;36:595-600
47. Viereck S, Moller TP, Ersboll AK, et al. Recognising out-of-hospital cardiac arrest during emergency calls increases bystander cardiopulmonary resuscitation and survival. *Resuscitation* 2017;115:141-47.
48. Syvaaja S, Salo A, Uusaro A, et al. Witnessed out-of-hospital cardiac arrest- effects of emergency dispatch recognition. *Acta Anaesthesiol Scand* 2018;62:558-67.
49. Berdowski J, Beekhuis F, Zwinderman AH, et al. Importance of the first link: description and recognition of an out-of-hospital cardiac arrest in an emergency call. *Circulation* 2009;119:2096-102.
50. Nichol G, Cobb LA, Yin L, et al. Briefer activation time is associated with better outcomes after out-of-hospital cardiac arrest. *Resuscitation* 2016;107:139-44.
51. Ko SY, Shin SD, Ro YS, et al. Effect of detection time interval for out-of-hospital cardiac arrest on outcomes in dispatcher-assisted cardiopulmonary resuscitation: A nationwide observational study. *Resuscitation* 2018;129:61-69.
52. Ko SY, Shin SD, Song KJ, et al. Effect of awareness time interval for out-of-hospital cardiac arrest on outcomes: A nationwide observational study. *Resuscitation* 2020;147:43-52.
53. Panchal AR, Berg KM, Cabanas JG, et al. 2019 American Heart Association Focused Update on Systems of Care: Dispatcher-Assisted Cardiopulmonary Resuscitation and Cardiac Arrest Centers: An Update to the American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation* 2019;140:e895-e903.
54. Soar J, Maconochie I, Wyckoff MH, et al. 2019 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations: Summary From the Basic Life Support; Advanced Life Support; Pediatric Life Support; Neonatal Life Support; Education, Implementation, and Teams; and First Aid Task Forces. *Circulation* 2019;140:e826-e880.
55. Rasmussen SE, Nebsbjerg MA, Bomholt KB, et al. Major Differences in the Use of Protocols for Dispatcher-Assisted Cardiopulmonary Resuscitation Among ILCOR Member Countries. *Open Access Emerg Med* 2020;12:67-71.
56. Deakin C, Brown S, Jewkes F, et al. Resuscitation Council (UK) Guidelines 2015. Prehospital resuscitation. Available from: <https://www.resus.org.uk/resuscitation-guidelines/prehospital-resuscitation/> [last accessed 19th November 2020].
57. Schwarzkopf M, Yin L, Hergert L, et al. Seizure-like presentation in OHCA creates barriers to dispatch recognition of cardiac arrest. *Resuscitation* 2020;156:230-36.
58. Nikolaou N, Dainty KN, Couper K, et al. A systematic review and meta-analysis of the effect of dispatcher-assisted CPR on outcomes from sudden cardiac arrest in adults and children. *Resuscitation* 2019;138:82-105.
59. Noel L, Jaeger D, Baert V, et al. Effect of bystander CPR initiated by a dispatch centre following out-of-hospital cardiac arrest on 30-day survival: Adjusted results from the French National Cardiac Arrest Registry. *Resuscitation* 2019;144:91-98
60. Lee YJ, Hwang SS, Shin SD, et al. Effect of National Implementation of Telephone CPR Program to Improve Outcomes from Out-of-Hospital Cardiac Arrest: an Interrupted Time-Series Analysis. *J Korean Med Sci* 2018;33:e328.
61. Shibahashi K, Ishida T, Kuwahara Y, et al. Effects of dispatcher-initiated telephone cardiopulmonary resuscitation after out-of-hospital cardiac arrest: A nationwide, population-based, cohort study. *Resuscitation* 2019;144:6-14

62. [no authors listed]. Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Part 3: adult basic life support. The American Heart Association in collaboration with the International Liaison Committee on Resuscitation. *Circulation* 2000;102(8 Suppl):I22-59.
63. Waalewijn RA, Nijpels MA, Tijssen JG, et al. Prevention of deterioration of ventricular fibrillation by basic life support during out-of-hospital cardiac arrest. *Resuscitation* 2002;54:31-6.
64. Song J, Guo W, Lu X, et al. The effect of bystander cardiopulmonary resuscitation on the survival of out-of-hospital cardiac arrests: a systematic review and meta-analysis. *Scand J Trauma Resusc Emerg Med* 2018;26:86.
65. Sondergaard KB, Wissenberg M, Gerds TA, et al. Bystander cardiopulmonary resuscitation and long-term outcomes in out-of-hospital cardiac arrest according to location of arrest. *Eur Heart J* 2019;40:309-18.
66. Geri G, Fahrenbruch C, Meischke H, et al. Effects of bystander CPR following out-of-hospital cardiac arrest on hospital costs and long-term survival. *Resuscitation* 2017;115:129-34.
67. Yeung J, Okamoto D, Soar J, et al. AED training and its impact on skill acquisition, retention and performance--a systematic review of alternative training methods. *Resuscitation* 2011;82:657-64.
68. Maconochie IK, Bingham R, Eich C, et al. European Resuscitation Council Guidelines for Resuscitation 2015: Section 6. Paediatric life support. *Resuscitation* 2015;95:223-48.
69. Holmberg MJ, Vognsen M, Andersen MS, et al. Bystander automated external defibrillator use and clinical outcomes after out-of-hospital cardiac arrest: A systematic review and meta-analysis. *Resuscitation* 2017;120:77-87.
70. Doan TN, Schultz BV, Rashford S, et al. Surviving out-of-hospital cardiac arrest: The important role of bystander interventions. *Australas Emerg Care* 2020;23:47-54.
71. Scquizzato T, Landoni G, Paoli A, et al. Effects of COVID-19 pandemic on out-of-hospital cardiac arrests: A systematic review. *Resuscitation* 2020 [E-pub ahead of print]
72. Lim ZJ, Reddy MP, Afroz A, et al. Incidence and outcome of out-of-hospital cardiac arrests in the COVID-19 era: A systematic review and meta-analysis. *Resuscitation* 2020 [E-pub ahead of print]
73. Majewski D, Ball S, Finn J. Systematic review of the relationship between comorbidity and out-of-hospital cardiac arrest outcomes. *BMJ Open* 2019;9:e031655.
74. Pasupula DK, Bhat AG, Meera SJ, et al. Influence of comorbidity on survival after out-of-hospital cardiac arrest in the United States. *Resuscitation* 2019;145:21-25.
75. Nolan JP, Berg RA, Callaway CW, et al. The present and future of cardiac arrest care: international experts reach out to caregivers and healthcare authorities. *Intensive Care Med* 2018;44:823-32.
76. Masterson S, Wright P, O'Donnell C, et al. Urban and rural differences in out-of-hospital cardiac arrest in Ireland. *Resuscitation* 2015;91:42-47.
77. Starks MA, Schmicker RH, Peterson ED, et al. Association of Neighborhood Demographics With Out-of-Hospital Cardiac Arrest Treatment and Outcomes: Where You Live May Matter. *JAMA Cardiol* 2017;2:1110-18.
78. Sasson C, Magid DJ, Chan P, et al. Association of neighborhood characteristics with bystander-initiated CPR. *N Engl J Med* 2012;367:1607-15.
79. Blewer AL, Schmicker RH, Morrison LJ, et al. Variation in Bystander Cardiopulmonary Resuscitation Delivery and Subsequent Survival From Out-of-Hospital Cardiac Arrest Based on Neighborhood-Level Ethnic Characteristics. *Circulation* 2020;141:34-41.
80. Brown TP, Booth S, Hawkes CA, et al. Characteristics of neighbourhoods with high incidence of out-of-hospital cardiac arrest and low bystander cardiopulmonary resuscitation rates in England. *Eur Heart J Qual Care Clin Outcomes* 2019;5:51-62.
81. Buick JE, Ray JG, Kiss A, et al. The association between neighborhood effects and out-of-hospital cardiac arrest outcomes. *Resuscitation* 2016;103:14-19.
82. Parikh PB, Hassan L, Qadeer A, et al. Association between sex and mortality in adults with in-hospital and out-of-hospital cardiac arrest: A systematic review and meta-analysis. *Resuscitation* 2020;155:119-24.
83. Dicker B, Conaglen K, Howie G. Gender and survival from out-of-hospital cardiac arrest: a New Zealand registry study. *Emerg Med J* 2018;35:367-71.
84. Drennan IR, Strum RP, Byers A, et al. Out-of-hospital cardiac arrest in high-rise buildings: delays to patient care and effect on survival. *CMAJ* 2016;188:413-19.

85. Kobayashi D, Kitamura T, Kiyohara K, et al. High-rise buildings and neurologically favorable outcome after out-of-hospital cardiac arrest. *Int J Cardiol* 2016;224:178-82.
86. Masterson S, McNally B, Cullinan J, et al. Out-of-hospital cardiac arrest survival in international airports. *Resuscitation* 2018;127:58-62.
87. Smith CM, Colquhoun MC. Out-of-hospital cardiac arrest in schools: A systematic review. *Resuscitation* 2015;96:296-302.
88. Page RL, Husain S, White LY, et al. Cardiac arrest at exercise facilities: implications for placement of automated external defibrillators. *J Am Coll Cardiol* 2013;62:2102-9.
89. Resuscitation Academy (2012). Ten Steps for Improving Survival from Sudden Cardiac Arrest. Available from: [http://www.resuscitationacademy.org/downloads/ebook/TenStepsforImprovingSurvivalFromSuddenCardiacArrest-RA-eBook-PDFFinal-v1\\_2.pdf](http://www.resuscitationacademy.org/downloads/ebook/TenStepsforImprovingSurvivalFromSuddenCardiacArrest-RA-eBook-PDFFinal-v1_2.pdf) [last accessed 19th November 2020].
90. Soreide E, Morrison L, Hillman K, et al. The formula for survival in resuscitation. *Resuscitation* 2013;84:1487-93.
91. McCarthy JJ, Carr B, Sasson C, et al. Out-of-Hospital Cardiac Arrest Resuscitation Systems of Care: A Scientific Statement From the American Heart Association. *Circulation* 2018;137:e645-e660.
92. Institute of Medicine 2015. Strategies to Improve Cardiac Arrest Survival: A Time to Act. Washington, DC: The National Academies Press. <https://doi.org/10.17226/21723>
93. Lick CJ, Aufderheide TP, Niskanen RA, et al. Take Heart America: A comprehensive, community-wide, systems-based approach to the treatment of cardiac arrest. *Crit Care Med* 2011;39:26-33.
94. van Diepen S, Abella BS, Bobrow BJ, et al. Multistate implementation of guideline-based cardiac resuscitation systems of care: description of the HeartRescue project. *Am Heart J* 2013;166:647-53
95. van Diepen S, Girotra S, Abella BS, et al. Multistate 5-Year Initiative to Improve Care for Out-of-Hospital Cardiac Arrest: Primary Results From the HeartRescue Project. *J Am Heart Assoc* 2017;6:e005716
96. Wissenberg M, Lippert FK, Folke F, et al. Association of national initiatives to improve cardiac arrest management with rates of bystander intervention and patient survival after out-of-hospital cardiac arrest. *JAMA* 2013;310:1377-84.
97. Okubo M, Kiyohara K, Iwami T, et al. Nationwide and regional trends in survival from out-of-hospital cardiac arrest in Japan: A 10-year cohort study from 2005 to 2014. *Resuscitation* 2017;115:120-8.
98. Tay PJM, Pek PP, Fan Q, et al. Effectiveness of a community based out-of-hospital cardiac arrest (OHCA) interventional bundle: Results of a pilot study. *Resuscitation* 2020;146:220-8.
99. Department of Health (2013). Cardiovascular Disease Outcomes Strategy. Available from: [https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/217118/9387-2900853-CVD-Outcomes\\_web1.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/217118/9387-2900853-CVD-Outcomes_web1.pdf) [last accessed 19th November 2020].
100. OHCA Steering Group (March 2017). Resuscitation to Recovery. Available from: <https://www.resus.org.uk/sites/default/files/2020-05/Resuscitation%20To%20Recovery.pdf> [last accessed 19th November 2020].
101. Welsh Government (June 2017). Out of Hospital Cardiac Arrest Plan. Available from: <https://gov.wales/sites/default/files/publications/2019-03/out-of-hospital-cardiac-arrest-plan.pdf> [last accessed 19th November 2020].
102. The Scottish Government (2015). Out-of-hospital cardiac arrest. A strategy for Scotland. Available from: <http://www.gov.scot/Resource/0047/00474154.pdf> [last accessed 19th November 2020].
103. Department of Health Northern Ireland (2014). Community Resuscitation Strategy Northern Ireland <https://www.health-ni.gov.uk/sites/default/files/publications/dhssps/community-resuscitation-strategy-2014.pdf> [last accessed 19th November 2020].
104. Association of Ambulance Services Chief Executives, National Ambulance Service Medical Directors. (November 2017). Statements of Best Clinical Practice. Adult Cardiac Arrest Care. November 2017 - version 4.

105. British Heart Foundation (2020). Restart A Heart Day. Available from: <https://www.bhf.org.uk/how-you-can-help/how-to-save-a-life/cpr-training-in-schools/restart-a-heart-day> [last accessed 19th November 2020].
106. European Resuscitation Council (2019). World Restart a Heart Day. Available from: <https://www.erc.edu/about/restart> [last accessed 19th November 2020].
107. Resuscitation Council UK (2020). CPR in Schools. Available from: <https://www.resus.org.uk/public-resource/cpr-schools> [last accessed 19th November 2020].
108. Department for Education (Sep 2018). Automated External Defibrillators (AEDs). A guide for schools. Available from: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/739575/AED\\_guide\\_for\\_schools\\_Sept\\_2018.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/739575/AED_guide_for_schools_Sept_2018.pdf) [last accessed 19th November 2020].
109. British Heart Foundation (2019). The Circuit - The National Defibrillator Network. Available from: <https://www.thecircuit.uk> [last accessed 19th November 2020].
110. Atkins DL. Realistic expectations for public access defibrillation programs. *Curr Opin Crit Care* 2010;16:191-95.
111. Smith CM, Lim Choi Keung SN, Khan MO, et al. Barriers and facilitators to public access defibrillation in out-of-hospital cardiac arrest: a systematic review. *Eur Heart J Qual Care Clin Outcomes* 2017;3:264-73.
112. van Alem AP, Vrenken RH, de Vos R, et al. Use of automated external defibrillator by first responders in out of hospital cardiac arrest: prospective controlled trial. *BMJ* 2003;327(7427):1312.
113. Bardy GH, Lee KL, Mark DB, et al. Home use of automated external defibrillators for sudden cardiac arrest. *N Engl J Med* 2008;358:1793-804.
114. Hallstrom AP, Ornato JP, Weisfeldt M, et al. Public-access defibrillation and survival after out-of-hospital cardiac arrest. *N Engl J Med* 2004;351:637-46.
115. Sterne JA, Hernan MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. *BMJ* 2016;355:i4919.
116. Cady CE, Weaver MD, Pirralo RG, et al. Effect of emergency medical technician-placed Combitubes on outcomes after out-of-hospital cardiopulmonary arrest. *Prehosp Emerg Care* 2009;13:495-9.
117. Weisfeldt ML, Sitlani CM, Ornato JP, et al. Survival after application of automatic external defibrillators before arrival of the emergency medical system: evaluation in the resuscitation outcomes consortium population of 21 million. *J Am Coll Cardiol* 2010;55:1713-20.
118. Berdowski J, Blom MT, Bardai A, et al. Impact of onsite or dispatched automated external defibrillator use on survival after out-of-hospital cardiac arrest. *Circulation* 2011;124:2225-32.
119. Lijovic M, Bernard S, Nehme Z, et al. Public access defibrillation—results from the Victorian Ambulance Cardiac Arrest Registry. *Resuscitation* 2014;85:1739-44.
120. Kitamura T, Kiyohara K, Sakai T, et al. Public-Access Defibrillation and Out-of-Hospital Cardiac Arrest in Japan. *N Engl J Med* 2016;375:1649-59.
121. Kiyohara K, Kitamura T, Sakai T, et al. Public-access AED pad application and outcomes for out-of-hospital cardiac arrests in Osaka, Japan. *Resuscitation* 2016;106:70-5.
122. Bækgaard JS, Viereck S, Møller TP, et al. The Effects of Public Access Defibrillation on Survival After Out-of-Hospital Cardiac Arrest: A Systematic Review of Observational Studies. *Circulation* 2017;136:954-65.
123. Wells GA, Shea B, Oconnell D, et al. (2014). The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. Available from: [http://www.ohri.ca/programs/clinical\\_epidemiology/oxford.asp](http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp) [last accessed 19th November 2020].
124. Resuscitation Council UK (May 2020). Quality Standards: CPR and AED training in the community. Available from: <https://www.resus.org.uk/print/pdf/node/540> [last accessed 19th November 2020].
125. Resuscitation Council UK, British Heart Foundation (December 2019). A guide to Automated External Defibrillators (AEDs). Available from: [https://www.resus.org.uk/sites/default/files/2020-03/AED\\_Guide\\_2019-12-04.pdf](https://www.resus.org.uk/sites/default/files/2020-03/AED_Guide_2019-12-04.pdf) [last accessed 19th November 2020].

126. Perkins GD, Colquhoun M, Deakin CD, et al. Resuscitation Council (UK) Guidelines 2015. Adult basic life support and automated external defibrillation. Available from: <https://www.resus.org.uk/resuscitation-guidelines/adult-basic-life-support-and-automated-external-defibrillation/> [last accessed 19th November 2020].
127. Resuscitation Council UK (2018). CPR, AEDs and the law. Available from: <https://www.resus.org.uk/sites/default/files/2020-05/CPR%20AEDs%20and%20the%20law%20%285%29.pdf> [last accessed 19th November 2020].
128. Colquhoun MC, Chamberlain DA, Newcombe RG, et al. A national scheme for public access defibrillation in England and Wales: early results. *Resuscitation* 2008;78:275-80.
129. British Heart Foundation (Undated). Hundreds of communities to be equipped with defibrillators, following £1 million government funding. Available from: <https://www.bhf.org.uk/how-you-can-help/how-to-save-a-life/defibrillators/apply-for-a-public-access-defibrillator> [last accessed 19th November 2020].
130. Calle PA, Mpotos N. How to prove without randomised controlled trials that automated external defibrillators used by the public save lives? *Heart* 2018;104:1315-16.
131. Kobayashi D, Sado J, Kiyohara K, et al. Public location and survival from out-of-hospital cardiac arrest in the public-access defibrillation era in Japan. *J Cardiol* 2020;75:97-104
132. Pollack RA, Brown SP, Rea T, et al. Impact of Bystander Automated External Defibrillator Use on Survival and Functional Outcomes in Shockable Observed Public Cardiac Arrests. *Circulation* 2018;137:2104-13.
133. Riddersholm S, Kragholm K, Mortensen RN, et al. Association of bystander interventions and hospital length of stay and admission to intensive care unit in out-of-hospital cardiac arrest survivors. *Resuscitation* 2017;119:99-106.
134. Kragholm K, Wissenberg M, Mortensen RN, et al. Bystander Efforts and 1-Year Outcomes in Out-of-Hospital Cardiac Arrest. *N Engl J Med* 2017;376:1737-47.
135. Berdowski J, Kuiper MJ, Dijkgraaf MGW, et al. Survival and health care costs until hospital discharge of patients treated with onsite, dispatched or without automated external defibrillator. *Resuscitation* 2010;81:962-67.
136. Ringh M, Jonsson M, Nordberg P, et al. Survival after Public Access Defibrillation in Stockholm, Sweden--A striking success. *Resuscitation* 2015;91:1-7.
137. Blom MT, Beesems SG, Homma PCM, et al. Improved survival after out-of-hospital cardiac arrest and use of automated external defibrillators. *Circulation* 2014;130:1868-75.
138. Brown AM, Rittenberger JC, Ammon CM, et al. In-flight automated external defibrillator use and consultation patterns. *Prehosp Emerg Care* 2010;14:235-39.
139. Caffrey SL, Willoughby PJ, Pepe PE, et al. Public Use of Automated External Defibrillators. *N Engl J Med* 2002;347:1242-47.
140. MacDonald RD, Mottley JL, Weinstein C. Impact of prompt defibrillation on cardiac arrest at a major international airport. *Prehosp Emerg Care* 2002;6:1-5.
141. Page RL, Joglar JA, Kowal RC, et al. Use of automated external defibrillators by a U.S. airline. *N Engl J Med* 2000;343:1210-16.
142. Bertrand C, Rodriguez Redington P, Lecarpentier E, et al. Preliminary report on AED deployment on the entire Air France commercial fleet: a joint venture with Paris XII University Training Programme. *Resuscitation* 2004;63:175-81.
143. O'Rourke MF, Donaldson E, Geddes JS. An airline cardiac arrest program. *Circulation* 1997;96:2849-53.
144. Valenzuela TD, Roe DJ, Nichol G, et al. Outcomes of rapid defibrillation by security officers after cardiac arrest in casinos. *N Engl J Med* 2000;343:1206-9.
145. Fedoruk JC, Paterson D, Hlynka M, et al. Rapid on-site defibrillation versus community program. *Prehosp Disaster Med* 2002;17:102-6.
146. Kiyohara K, Sado J, Kitamura T, et al. Public-access automated external defibrillation and bystander-initiated cardiopulmonary resuscitation in schools: a nationwide investigation in Japan. *Europace* 2019;21:451-58.
147. Aschieri D, Penela D, Pelizzoni V, et al. Outcomes after sudden cardiac arrest in sports centres with and without on-site external defibrillators. *Heart* 2018;104:1344-49.
148. Kinoshita T, Tanaka S, Sagisaka R, et al. Mobile Automated External Defibrillator Response System during Road Races. *N Engl J Med* 2018;379:488-9.
149. National Institute for Health and Care Excellence (2012). Chapter 7: Assessing cost-effectiveness. In: The guidelines manual. Process and methods. Available from:

<https://www.nice.org.uk/process/pmg6/resources/the-guidelines-manual-pdf-2007970804933> pp101-115 [last accessed 19th November 2020].

150. Gold LS, Eisenberg M. Cost-effectiveness of automated external defibrillators in public places: pro. *Curr Opin Cardiol* 2007;22:1-4.
151. Moran PS, Teljeur C, Masterson S, et al. Cost-effectiveness of a national public access defibrillation programme. *Resuscitation* 2015;91:48-55.
152. Pell JP, Walker A, Cobbe SM. Cost-effectiveness of automated external defibrillators in public places: con. *Curr Opin Cardiol* 2007;22:5-10.
153. Sharieff W, Kaulback K. Assessing automated external defibrillators in preventing deaths from sudden cardiac arrest: an economic evaluation. *Int J Technol Assess Health Care* 2007;23:362-67.
154. Health Quality Ontario. Use of automated external defibrillators in cardiac arrest: an evidence-based analysis. *Ont Health Technol Assess Ser* 2005;5:1-29
155. Nichol G, Huszti E, Birnbaum A, et al. Cost-effectiveness of lay responder defibrillation for out-of-hospital cardiac arrest. *Ann Emerg Med* 2009;54:226-35.e1-2.
156. Folke F, Lippert FK, Nielsen SL, et al. Location of Cardiac Arrest in a City Center. Strategic Placement of Automated External Defibrillators in Public Locations. *Circulation* 2009;120:510-17.
157. Cram P, Vijan S, Fendrick AM. Cost-effectiveness of automated external defibrillator deployment in selected public locations. *J Gen Intern Med* 2003;18:745-54.
158. Walker A, Sirel JM, Marsden AK, et al. Cost effectiveness and cost utility model of public place defibrillators in improving survival after prehospital cardiopulmonary arrest. *BMJ* 2003;327(7427):1316.
159. Barry T, Doheny MC, Masterson S, et al. Community first responders for out-of-hospital cardiac arrest in adults and children. *Cochrane Database Syst Rev* 2019;7:CD012764.
160. Oving I, Masterson S, Tjelmeland IBM, et al. First-response treatment after out-of-hospital cardiac arrest: a survey of current practices across 29 countries in Europe. *Scand J Trauma Resusc Emerg Med* 2019;27:112.
161. Husain S, Eisenberg M. Police AED programs: a systematic review and meta-analysis. *Resuscitation* 2013;84:1184-91.
162. Ringh M, Rosenqvist M, Hollenberg J, et al. Mobile-Phone Dispatch of Laypersons for CPR in Out-of-Hospital Cardiac Arrest. *N Engl J Med* 2015;372:2316-25.
163. Stroop R, Kerner T, Strickmann B, et al. Mobile phone-based alerting of CPR-trained volunteers simultaneously with the ambulance can reduce the resuscitation-free interval and improve outcome after out-of-hospital cardiac arrest: A German, population-based cohort study. *Resuscitation* 2020;147:57-64
164. Pijls RWM, Nelemans PJ, Rahel BM, et al. A text message alert system for trained volunteers improves out-of-hospital cardiac arrest survival. *Resuscitation* 2016;105:182-87.
165. Pijls RWM, Nelemans PJ, Rahel BM, et al. Characteristics of a novel citizen rescue system for out-of-hospital cardiac arrest in the Dutch province of Limburg: relation to incidence and survival. *Neth Heart J* 2019;27:100-7.
166. Lee SY, Shin SD, Lee YJ, et al. Text message alert system and resuscitation outcomes after out-of-hospital cardiac arrest: A before-and-after population-based study. *Resuscitation* 2019;138:198-207.
167. Brooks SC, Simmons G, Worthington H, et al. The PulsePoint Respond mobile device application to crowdsource basic life support for patients with out-of-hospital cardiac arrest: Challenges for optimal implementation. *Resuscitation* 2016;98:20-26.
168. Zijlstra JA, Stieglis R, Riedijk F, et al. Local lay rescuers with AEDs, alerted by text messages, contribute to early defibrillation in a Dutch out-of-hospital cardiac arrest dispatch system. *Resuscitation* 2014;85:1444-49.
169. Ringh M, Fredman D, Nordberg P, et al. Mobile phone technology identifies and recruits trained citizens to perform CPR on out-of-hospital cardiac arrest victims prior to ambulance arrival. *Resuscitation* 2011;82:1514-18.
170. Scholten AC, van Manen JG, van der Worp WE, et al. Early cardiopulmonary resuscitation and use of Automated External Defibrillators by laypersons in out-of-hospital cardiac arrest using an SMS alert service. *Resuscitation* 2011;82:1273-78.
171. Berglund E, Claesson A, Nordberg P, et al. A smartphone application for dispatch of lay responders to out-of-hospital cardiac arrests. *Resuscitation* 2018;126:160-65.

172. Caputo ML, Muschietti S, Burkart R, et al. Lay persons alerted by mobile application system initiate earlier cardio-pulmonary resuscitation: A comparison with SMS-based system notification. *Resuscitation* 2017;114:73-78.
173. Auricchio A, Gianquintieri L, Burkart R, et al. Real-life time and distance covered by lay first responders alerted by means of smartphone-application: Implications for early initiation of cardiopulmonary resuscitation and access to automatic external defibrillators. *Resuscitation* 2019;141:182-87.
174. Smith CM, Wilson MH, Ghorbangholi A, et al. The use of trained volunteers in the response to out-of-hospital cardiac arrest - the GoodSAM experience. *Resuscitation* 2017;121:123-26.
175. Sarkisian L, Mickley H, Schakow H, et al. Global positioning system alerted volunteer first responders arrive before emergency medical services in more than four out of five emergency calls. *Resuscitation* 2020;152:170-76
176. Agerkov M, Nielsen AM, Hansen CM, et al. Public Access Defibrillation: Great benefit and potential but infrequently used. *Resuscitation* 2015;96:53-58.
177. Ho CL, Lui CT, Tsui KL, et al. Investigation of availability and accessibility of community automated external defibrillators in a territory in Hong Kong. *Hong Kong Med J* 2014;20:371-78.
178. Chan TCY, Li H, Lebovic G, et al. Identifying Locations for Public Access Defibrillators Using Mathematical Optimization. *Circulation* 2013;127:1801-9.
179. Sun CLF, Demirtas D, Brooks SC, et al. Overcoming Spatial and Temporal Barriers to Public Access Defibrillators Via Optimization. *J Am Coll Cardiol* 2016;68:836-45.
180. Fredman D, Svensson L, Ban Y, et al. Expanding the first link in the chain of survival - Experiences from dispatcher referral of callers to AED locations. *Resuscitation* 2016;107:129-34.
181. Hansen CM, Wissenberg M, Weeke P, et al. Automated external defibrillators inaccessible to more than half of nearby cardiac arrests in public locations during evening, nighttime, and weekends. *Circulation* 2013;128:2224-31.
182. National Institutes of Health (June 24th 2019). Multifaceted Intervention for Increasing Performance of CPR by Laypersons in Out-of-hospital Cardiac Arrest (DISPATCH). Available from: <https://clinicaltrials.gov/ct2/show/NCT03633370> [last accessed 19th November 2020].
183. National Institutes of Health (February 5th 2020). The Scandinavian AED and Mobile Bystander Activation Trial (SAMBA). Available from: <https://clinicaltrials.gov/ct2/show/NCT02992873> [Last accessed 19th November 2020].
184. NHS (January 2019). The NHS Long Term Plan. Available from: <https://www.longtermplan.nhs.uk/wp-content/uploads/2019/08/nhs-long-term-plan-version-1.2.pdf> [last accessed 19th November 2020].
185. Atkins L, Francis J, Islam R, et al. A guide to using the Theoretical Domains Framework of behaviour change to investigate implementation problems. *Implement Sci* 2017;12:77.
186. Ranney ML, Meisel ZF, Choo EK, et al. Interview-Based Qualitative Research in Emergency Care Part II: Data Collection, Analysis and Results Reporting. *Acad Emerg Med* 2015;22:1103-12.
187. Mays N, Pope C. Quality in qualitative health research. In: Pope C, Mays N, eds. *Qualitative Research in Health Care*. 3rd ed. Oxford: Blackwell 2006:82-101.
188. Onwuegbezie A, Leech N. Linking Research Questions to Mixed Methods Data Analysis Procedures. *Qualitative Report* 2006;11:474-98. Available from: <http://nsuworks.nova.edu/cgi/viewcontent.cgi?article=1663&context=tqr> [last accessed 19th November 2020].
189. Smith CM, Griffiths F, Fothergill RT, et al. Identifying and overcoming barriers to Automated External Defibrillator use by GoodSAM volunteer first-responders in out-of-hospital cardiac arrest using the Theoretical Domains Framework and Behaviour Change Wheel. A qualitative study. *BMJ Open* 2020;10:e034908
190. Ormston R, Spencer L, Bernard M, et al. The Foundations of Qualitative Research. In: Ritchie J, Lewis J, McNaughton Nicholls C, et al., eds. *Qualitative Research Practice: A Guide for Social Science Students and Researchers*. 2nd ed. London: SAGE 2014:1-25.
191. Pope C, Mays N. Qualitative methods in health research. In: Pope C, Mays N, eds. *Qualitative Research in Health Care*. 3rd ed. Oxford: Blackwell Publishing 2006.
192. Curry LA, Nembhard IM, Bradley EH. Qualitative and mixed methods provide unique contributions to outcomes research. *Circulation* 2009;119:1442-52.

193. Spencer L, Ritchie J, Ormston R, et al. Analysis: Principles and Processes. *Qualitative Research Practice: A Guide for Social Science Students and Researchers*. London: SAGE: SAGE 2013:269-94.
194. Gale NK, Heath G, Cameron E, et al. Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Med Res Methodol* 2013;13:117.
195. Ritchie J, Lewis J, Elam G, et al. Designing and selecting samples. In: Ritchie J, Lewis J, McNaughton Nicholls C, et al., eds. *Qualitative Research Practice: A Guide for Social Science Students and Researchers*. 2nd ed. London: SAGE 2014:111-46.
196. Cane J, O'Connor D, Michie S. Validation of the theoretical domains framework for use in behaviour change and implementation research. *Implement Sci* 2012;7:37.
197. Huig IC, Boonstra L, Gerritsen PC, et al. The availability, condition and employability of automated external defibrillators in large city centres in the Netherlands. *Resuscitation* 2014;85:1324-29.
198. Alexander KE, Brijnath B, Mazza D. Barriers and enablers to delivery of the Healthy Kids Check: an analysis informed by the Theoretical Domains Framework and COM-B model. *Implement Sci* 2014;9:60.
199. Michie S, Atkins L, West R. *The Behaviour Change Wheel: A Guide To Designing Interventions*. London: Silverback Publishing 2014.
200. Michie S, Wood CE, Johnston M, et al. Behaviour change techniques: the development and evaluation of a taxonomic method for reporting and describing behaviour change interventions (a suite of five studies involving consensus methods, randomised controlled trials and analysis of qualitative data). *Health Technol Assess* 2015;19:1-188.
201. Davis R, Campbell R, Hildon Z, et al. Theories of behaviour and behaviour change across the social and behavioural sciences: a scoping review. *Health Psychol Rev* 2015;9:323-44.
202. Squires JE, Sullivan K, Eccles MP, et al. Are multifaceted interventions more effective than single-component interventions in changing health-care professionals' behaviours? An overview of systematic reviews. *Implement Sci* 2014;9:152.
203. Medical Research Council (2008). Developing and evaluating complex interventions: new guidance. Available from: <http://www.mrc.ac.uk/complexinterventionsguidance> [last accessed 19th November 2020]
204. Craig P, Dieppe P, Macintyre S, et al. Developing and evaluating complex interventions: the new Medical Research Council guidance. *BMJ* 2008;337(7619):a1655
205. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ* 2009;339:b2535.
206. von Elm E, Altman DG, Egger M, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *BMJ* 2007;335(7624):806-8.
207. O'Brien BC, Harris IB, Beckman TJ, et al. Standards for Reporting Qualitative Research: A Synthesis of Recommendations. *Acad Med* 2014;89:1245-51.
208. Munn Z, Peters MDJ, Stern C, et al. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Med Res Methodol* 2018;18:143.
209. Guyatt GH, Oxman AD, Vist GE, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ* 2008;336(7650):924-26.
210. Aagaard R, Grove EL, Mikkelsen R, et al. Limited public ability to recognise and understand the universal sign for automated external defibrillators. *Heart* 2016;102:770-74.
211. Ashimi AO, Cobbe SM, Pell JP. Scottish survey of public place defibrillators. *Scott Med J* 2010;55:8-10.
212. Bartimus HA, Rea TD, Eisenberg MS. Prevalence of automated external defibrillators at cardiac arrest high-risk sites. *Prehosp Emerg Care* 2004;8:280-83.
213. Bogle B, Mehrotra S, Chiampas G, et al. Assessment of knowledge and attitudes regarding automated external defibrillators and cardiopulmonary resuscitation among American University students. *Emerg Med J* 2013;30:837-41.
214. Brooks SC, Hsu JH, Tang SK, et al. Determining risk for out-of-hospital cardiac arrest by location type in a Canadian urban setting to guide future public access defibrillator placement. *Ann Emerg Med* 2013;61:530-38.

215. Brooks B, Chan S, Lander P, et al. Public knowledge and confidence in the use of public access defibrillation. *Heart* 2015;101:967-71.
216. Chrisinger BW, Grossestreuer AV, Laguna MC, et al. Characteristics of automated external defibrillator coverage in Philadelphia, PA, based on land use and estimated risk. *Resuscitation* 2016;109:9-15.
217. Coris EE, Sahebzamani F, Walz S, et al. Automated external defibrillators in National Collegiate Athletic Association Division I Athletics. *Am J Sports Med* 2004;32:744-54.
218. Cronin O, Jordan J, Quigley F, et al. Prepared for sudden cardiac arrest? A cross-sectional study of automated external defibrillators in amateur sport. *Br J Sports Med* 2013;47:1171-74.
219. Davies E, Maybury B, Colquhoun M, et al. Public access defibrillation: psychological consequences in responders. *Resuscitation* 2008;77:201-6.
220. Deakin CD, Shewry E, Gray HH. Public access defibrillation remains out of reach for most victims of out-of-hospital sudden cardiac arrest. *Heart* 2014;100:619-23.
221. Ecker R, Rea TD, Meischke H, et al. Dispatcher assistance and automated external defibrillator performance among elders. *Acad Emerg Med* 2001;8:968-73.
222. Engdahl J, Herlitz J. Localization of out-of-hospital cardiac arrest in Goteborg 1994-2002 and implications for public access defibrillation. *Resuscitation* 2005;64:171-75.
223. Fan KL, Leung LP, Poon HT, et al. Public knowledge of how to use an automatic external defibrillator in out-of-hospital cardiac arrest in Hong Kong. *Hong Kong Med J* 2016;22:582-88.
224. Gilchrist S, Schieb L, Mukhtar Q, et al. A summary of public access defibrillation laws, United States, 2010. *Prev Chronic Dis* 2012;9:E71.
225. Griffis HM, Band RA, Ruther M, et al. Employment and residential characteristics in relation to automated external defibrillator locations. *Am Heart J* 2016;172:185-91.
226. Groh WJ, Birnbaum A, Barry A, et al. Characteristics of volunteers responding to emergencies in the Public Access Defibrillation Trial. *Resuscitation* 2007;72:193-99.
227. Hansen CM, Lippert FK, Wissenberg M, et al. Temporal trends in coverage of historical cardiac arrests using a volunteer-based network of automated external defibrillators accessible to laypersons and emergency dispatch centers. *Circulation* 2014;130:1859-67.
228. Harrison-Paul R, Timmons S, van Schalkwyk WD. Training lay-people to use automatic external defibrillators: are all of their needs being met? *Resuscitation* 2006;71:80-8.
229. Harve H, Jokela J, Tissari A, et al. Can untrained laypersons use a defibrillator with dispatcher assistance? *Acad Emerg Med* 2007;14:624-28.
230. Haskell SE, Post M, Cram P, et al. Community public access sites: compliance with American Heart Association recommendations. *Resuscitation* 2009;80:854-58.
231. Hubble MW, Bachman M, Price R, et al. Willingness of high school students to perform cardiopulmonary resuscitation and automated external defibrillation. *Prehosp Emerg Care* 2003;7:219-24.
232. Kozłowski D, Kłosiewicz T, Kowalczyk A, et al. The knowledge of public access to defibrillation in selected cities in Poland. *Arch Med Sci* 2013;9:27-33.
233. Kuramoto N, Morimoto T, Kubota Y, et al. Public perception of and willingness to perform bystander CPR in Japan. *Resuscitation* 2008;79:475-81.
234. Leung AC, Asch DA, Lozada KN, et al. Where are lifesaving automated external defibrillators located and how hard is it to find them in a large urban city? *Resuscitation* 2013;84:910-14.
235. Levy MJ, Seaman KG, Millin MG, et al. A poor association between out-of-hospital cardiac arrest location and public automated external defibrillator placement. *Prehosp Disaster Med* 2013;28:342-47.
236. Lin B-C, Chen C-W, Chen C-C, et al. Spatial decision on allocating automated external defibrillators (AED) in communities by multi-criterion two-step floating catchment area (MC2SFCA). *Int J Health Geogr* 2016;15:17.
237. Lubin J, Chung SS, Williams K. An assessment of public attitudes toward automated external defibrillators. *Resuscitation* 2004;62:43-47.
238. Maes F, Marchandise S, Boileau L, et al. Evaluation of a new semiautomated external defibrillator technology: a live cases video recording study. *Emerg Med J* 2015;32:481-85.

239. McDonald DD, Martin D, Foley D, et al. Motivating people to learn cardiopulmonary resuscitation and use of automated external defibrillators. *J Cardiovasc Nurs* 2010;25:69-74.
240. Meischke HW, Rea TD, Eisenberg MS, et al. Intentions to use an automated external defibrillator during a cardiac emergency among a group of seniors trained in its operation. *Heart Lung* 2002;31:25-29.
241. Moon S, Vadeboncoeur TF, Kortuem W, et al. Analysis of out-of-hospital cardiac arrest location and public access defibrillator placement in Metropolitan Phoenix, Arizona. *Resuscitation* 2015;89:43-49.
242. Myers JB, French D, Webb W. Lack of integration of automated external defibrillators with EMS response may reduce lifesaving potential of public-access defibrillation. *Prehosp Emerg Care* 2005;9:339-43.
243. Nielsen AM, Folke F, Lippert FK, et al. Use and benefits of public access defibrillation in a nation-wide network. *Resuscitation* 2013;84:430-34.
244. Nielsen AM, Isbye DL, Lippert FK, et al. Can mass education and a television campaign change the attitudes towards cardiopulmonary resuscitation in a rural community? *Scand J Trauma Resusc Emerg Med* 2013;21:39.
245. Ong MEH, Quah JLJ, Ho AFW, et al. National population based survey on the prevalence of first aid, cardiopulmonary resuscitation and automated external defibrillator skills in Singapore. *Resuscitation* 2013;84:1633-36.
246. Peberdy MA, Ottingham LV, Groh WJ, et al. Adverse events associated with lay emergency response programs: the public access defibrillation trial experience. *Resuscitation* 2006;70:59-65.
247. Pell JP, Sirel JM, Marsden AK, et al. Potential impact of public access defibrillators on survival after out of hospital cardiopulmonary arrest: retrospective cohort study. *BMJ* 2002;325(7363):515.
248. Ragin DF, Holohan JA, Ricci EM, et al. Shocking a community into action: a social marketing approach to cardiac arrests. *J Health Soc Policy* 2005;20:49-70.
249. Rea T, Blackwood J, Damon S, et al. A link between emergency dispatch and public access AEDs: potential implications for early defibrillation. *Resuscitation* 2011;82:995-98.
250. Richardson LD, Gunnels MD, Groh WJ, et al. Implementation of community-based public access defibrillation in the PAD trial. *Acad Emerg Med* 2005;12:688-97.
251. Ringh M, Herlitz J, Hollenberg J, et al. Out of hospital cardiac arrest outside home in Sweden, change in characteristics, outcome and availability for public access defibrillation. *Scand J Trauma Resusc Emerg Med* 2009;17:18.
252. Riyapan S, Lubin J. Emergency dispatcher assistance decreases time to defibrillation in a public venue: a randomized controlled trial. *Am J Emerg Med* 2016;34:590-93.
253. Sakai T, Iwami T, Kitamura T, et al. Effectiveness of the new 'Mobile AED Map' to find and retrieve an AED: A randomised controlled trial. *Resuscitation* 2011;82:69-73.
254. Schober P, van Dehn FB, Bierens JJLM, et al. Public access defibrillation: time to access the public. *Ann Emerg Med* 2011;58:240-47.
255. Shams A, Raad M, Chams N, et al. Community involvement in out of hospital cardiac arrest. *Medicine (Baltimore)* 2016;95:e5091.
256. Sneath JZ, Lacey R. Marketing defibrillation training programs and bystander intervention support. *Health Mark Q* 2009;26:87-97.
257. Taniguchi T, Omi W, Inaba H. Attitudes toward automated external defibrillator use in Japan. *Resuscitation* 2008;79:288-91.
258. Taniguchi T, Sato K, Kurita A, et al. Attitudes toward automated external defibrillator use in Japan in 2011. *J Anesth* 2014;28:34-37.
259. Timmons S, Harrison-Paul R, Crosbie B. How do lay people come to trust the Automatic External Defibrillator? *Health, Risk & Society* 2008;10:207-20. DOI: 10.1080/13698570802160939
260. Timmons S, Crosbie B. Why do organisations implement automated external defibrillators? *Health, Risk & Society* 2014;16:355-69. DOI: 10.1080/13698575.2014.926314
261. Yoon CG, Jeong J, Kwon IH, et al. Availability and use of public access defibrillators in Busan Metropolitan City, South Korea. *Springerplus* 2016;5:1524.

262. Zijlstra JA, Beesems SG, De Haan RJ, et al. Psychological impact on dispatched local lay rescuers performing bystander cardiopulmonary resuscitation. *Resuscitation* 2015;92:115-21.
263. Zinckernagel L, Hansen CM, Rod MH, et al. A qualitative study to identify barriers to deployment and student training in the use of automated external defibrillators in schools. *BMC Emerg Med* 2017;17:3.
264. Enami M, Takei Y, Inaba H, et al. Differential effects of ageing and BLS training experience on attitude towards basic life support. *Resuscitation* 2011;82:577-83.
265. Gonzalez M, Leary M, Blewer AL, et al. Public knowledge of automatic external defibrillators in a large U.S. urban community. *Resuscitation* 2015;92:101-6.
266. Lee MJ, Hwang SO, Cha KC, et al. Influence of nationwide policy on citizens' awareness and willingness to perform bystander cardiopulmonary resuscitation. *Resuscitation* 2013;84:889-94.
267. McDonough A, Callan K, Egizio K, et al. Student perceptions of sudden cardiac arrest: a qualitative inquiry. *Br J Nurs* 2012;21:523-27.
268. Malta Hansen C, Rosenkranz SM, Folke F, et al. Lay Bystanders' Perspectives on What Facilitates Cardiopulmonary Resuscitation and Use of Automated External Defibrillators in Real Cardiac Arrests. *J Am Heart Assoc* 2017;6:e004572.
269. Hawkes CA, Brown TP, Booth S, et al. Attitudes to Cardiopulmonary Resuscitation and Defibrillator Use: A Survey of UK Adults in 2017. *J Am Heart Assoc* 2019;8:e008267.
270. Fortington LV, West L, Morgan D, et al. Implementing automated external defibrillators into community sports clubs/facilities: a cross-sectional survey of community club member preparedness for medical emergencies. *BMJ Open Sport Exerc Med* 2019;5:e000536.
271. Petruncio LM, French DM, Jauch EC. Public CPR and AED Knowledge: An Opportunity for Educational Outreach in South Carolina. *South Med J* 2018;111:349-52.
272. Boudreaux S, Broussard L. School Nurses' Perceived Barriers and Perceptual Influences When Implementing AED Programs. *J Sch Nurs* 2020;36:187-92.
273. Saberian S, Pendyala VS, Siebert VR, et al. Disparities Regarding Inadequate Automated External Defibrillator Training and Potential Barriers to Successful Cardiac Resuscitation in Public School Systems. *Am J Cardiol* 2018;122:1565-69.
274. Lupo R, Giordano G, Artioli G, et al. The use of an automatic defibrillator by non-sanitary personnel in sport areas: an Observational Study. *Acta Biomed* 2020;91(6-S):79-84.
275. Fortington LV, Bekker S, Morgan D, et al. "It Doesn't Make Sense for Us Not to Have One"-Understanding Reasons Why Community Sports Organizations Chose to Participate in a Funded Automated External Defibrillator Program. *Clin J Sport Med* 2019;29:324-28.
276. Deakin CD, Anfield S, Hodgetts GA. Underutilisation of public access defibrillation is related to retrieval distance and time-dependent availability. *Heart* 2018;104:1339-43.
277. Fan M, Fan KL, Leung LP. Walking Route-Based Calculation is Recommended for Optimizing Deployment of Publicly Accessible Defibrillators in Urban Cities. *J Am Heart Assoc* 2020;9:e014398.
278. Karlsson L, Malta Hansen C, Wissenberg M, et al. Automated external defibrillator accessibility is crucial for bystander defibrillation and survival: A registry-based study. *Resuscitation* 2019;136:30-37.
279. O'Callaghan PA, Swampillai J, Stiles MK. Availability of automated external defibrillators in Hamilton, New Zealand. *N Z Med J* 2019;132:75-82.
280. Sondergaard KB, Hansen SM, Pallisgaard JL, et al. Out-of-Hospital Cardiac Arrest: Probability of Bystander Defibrillation relative to Distance to Nearest Automated External Defibrillator. *Resuscitation* 2018;124:138-144
281. Fredman D, Haas J, Ban Y, et al. Use of a geographic information system to identify differences in automated external defibrillator installation in urban areas with similar incidence of public out-of-hospital cardiac arrest: a retrospective registry-based study. *BMJ Open* 2017;7:e014801.
282. Neves Briard J, de Montigny L, Ross D, et al. Is Distance to the Nearest Registered Public Automated Defibrillator Associated with the Probability of Bystander Shock for Victims of Out-of-Hospital Cardiac Arrest? *Prehosp Disaster Med* 2018;33:153-59.
283. Sidebottom DB, Potter R, Newitt LK, et al. Saving lives with public access defibrillation: A deadly game of hide and seek. *Resuscitation* 2018;128:93-96.

284. Fredman D, Ringh M, Svensson L, et al. Experiences and outcome from the implementation of a national Swedish automated external defibrillator registry. *Resuscitation* 2018;130:73-80.
285. Gardett I, Broadbent M, Scott G, et al. Availability and Use of an Automated External Defibrillator at Emergency Medical Dispatch. *Prehosp Emerg Care* 2019;23:683-90.
286. Owen DD, McGovern SK, Murray A, et al. Association of race and socioeconomic status with automatic external defibrillator training prevalence in the United States. *Resuscitation* 2018;127:100-4.
287. Grunau B, Humphries K, Stenstrom R, et al. Public access defibrillators: Gender-based inequities in access and application. *Resuscitation* 2020;150:17-22.
288. Boutilier J, Brooks S, Janmohamed A, et al. Optimizing a Drone Network to Deliver Automated External Defibrillators. *Circulation* 2017;135:2454-65.
289. Claesson A, Fredman D, Svensson L, et al. Unmanned aerial vehicles (drones) in out-of-hospital-cardiac-arrest. *Scand J Trauma Resusc Emerg Med* 2016;24:124.
290. Claesson A, Bäckman A, Ringh M, et al. Time to Delivery of an Automated External Defibrillator Using a Drone for Simulated Out-of-Hospital Cardiac Arrests vs Emergency Medical Services. *JAMA* 2017;317:2332-4.
291. Sanfridsson J, Sparrevik J, Hollenberg J, et al. Drone delivery of an automated external defibrillator – a mixed method simulation study of bystander experience. *Scand J Trauma Resusc Emerg Med* 2019;27:40.
292. Karam N, Narayanan K, Bougouin W, et al. Major regional differences in Automated External Defibrillator placement and Basic Life Support training in France: Further needs for coordinated implementation. *Resuscitation* 2017;118:49-54.
293. Huang C-Y, Wen T-H. Optimal installation locations for automated external defibrillators in Taipei 7-Eleven stores: using GIS and a genetic algorithm with a new stirring operator. *Comput Math Methods Med* 2014;2014:241435.
294. Tsai Y-S, Ko PC-I, Huang C-Y, et al. Optimizing locations for the installation of automated external defibrillators (AEDs) in urban public streets through the use of spatial and temporal weighting schemes. *Appl Geogr* 2012;35:394-404.
295. Deakin CD, Anfield S, Hodgetts GA. Which building types give optimal public access defibrillator coverage for out-of-hospital cardiac arrest? *Resuscitation* 2020;152:149-56.
296. Nishi T, Takei Y, Kamikura T, et al. Improper bystander-performed basic life support in cardiac arrests managed with public automated external defibrillators. *Am J Emerg Med* 2015;33:43-49.
297. Wilson MH, Hinds J, Grier G, et al. Impact brain apnoea - A forgotten cause of cardiovascular collapse in trauma. *Resuscitation* 2016;105:52-58.
298. GoodSAM (2020). GoodSAM code of conduct. Available from: <https://www.goodsamapp.org/codeofconduct> [last accessed 19th November 2020].
299. The National Archives. (2015) Social Action, Responsibility and Heroism Act 2015. Available from: <http://www.legislation.gov.uk/ukpga/2015/3/contents/enacted> [last accessed 19th November 2020].
300. GoodSAM (May 2018). Data and Privacy Policy. <https://www.goodsamapp.org/assets/pdf/DataProtectionPolicy.pdf> [last accessed 19th November 2020].
301. ter Avest E, Lambert E, de Coverly R, et al. Live video footage from scene to aid helicopter emergency medical service dispatch: a feasibility study. *Scand J Trauma Resusc Emerg Med* 2019;27:55.
302. GoodSAM (2020). NHS Volunteer Responders. Available from: <https://www.goodsamapp.org/NHS> [last accessed 19th November 2020].
303. Care Quality Commission (23rd May 2018). London Ambulance Service NHS Trust Inspection Report. Available from: [https://www.cqc.org.uk/sites/default/files/new\\_reports/AAAH3466.pdf](https://www.cqc.org.uk/sites/default/files/new_reports/AAAH3466.pdf) [last accessed 19th November 2020].
304. Care Quality Commission (13th June 2017). East Midlands Ambulance Service NHS Trust Inspection Report. Available from: [https://www.cqc.org.uk/sites/default/files/new\\_reports/AAAG3547.pdf](https://www.cqc.org.uk/sites/default/files/new_reports/AAAG3547.pdf) [last accessed 19th November 2020].
305. Pallant J. SPSS Survival Manual. 3rd ed. Maidenhead: Open University Press 2007.
306. Hair J, Black W, Babin B, et al. Multivariate data analysis. 7th ed. New Jersey: Pearson Education International 2010.

307. Agresti A. Building, Checking and Applying Logistic Regression Models. In: Agresti A, ed. *Categorical Data Analysis*. 3rd ed. Hoboken, New Jersey: Wiley 2013:p207-50.
308. OHCAO Registry (2017). *Epidemiology Report for the period January - December 2016 for the English Ambulance Services*. Available from: [https://warwick.ac.uk/fac/sci/med/research/ctu/trials/ohcao/publications/epidemiologyreports/anonymised\\_2016\\_final\\_epidemiology\\_report.pdf](https://warwick.ac.uk/fac/sci/med/research/ctu/trials/ohcao/publications/epidemiologyreports/anonymised_2016_final_epidemiology_report.pdf) [last accessed 19th November 2020].
309. OHCAO Registry (2018). *Out-of-Hospital Cardiac Arrest Outcomes Registry Epidemiology Report*. Available from: [https://warwick.ac.uk/fac/sci/med/research/ctu/trials/ohcao/publications/epidemiologyreports/ohcao\\_annual\\_report\\_2017\\_final.pdf](https://warwick.ac.uk/fac/sci/med/research/ctu/trials/ohcao/publications/epidemiologyreports/ohcao_annual_report_2017_final.pdf) [last accessed 19th November 2020]
310. Nichol G, Brown SP, Perkins GD, et al. What change in outcomes after cardiac arrest is necessary to change practice? Results of an international survey. *Resuscitation* 2016;107:115-20.
311. Resuscitation Council UK (2018). *Restart a Heart Day 2018 - 230,000 new UK lifesavers*. Available from: <https://www.resus.org.uk/about-us/news-and-events/230000-new-lifesavers-trained-thanks-restart-heart-2018> [last accessed 19th November 2020].
312. Gianquintieri L, Caiani E, Brambilla P, et al. Open data in Health Geo-Matics: mapping and evaluating publically accessible defibrillators. *ISPRS Archives* 2019;XLII-4/W14:63-70.
313. Ordnance Survey (2018). *A Guide to Coordinate Systems in Great Britain*. Available from: <https://www.ordnancesurvey.co.uk/documents/resources/guide-coordinate-systems-great-britain.pdf> [last accessed 19th November 2020].
314. Ordnance Survey (2010) *What's the difference between raster and vector mapping?* Available from: <https://www.ordnancesurvey.co.uk/blog/2010/03/raster-vs-vector/> [last accessed 19th November 2020].
315. Sun CLF, Karlsson L, Torp-Pedersen C, et al. Spatiotemporal AED optimization is generalizable. *Resuscitation* 2018;131:101-07.
316. Smida T, Willson C, Salerno J, et al. Can you get there from here? An analysis of walkability among PulsePoint CPR alert dispatches. *Resuscitation* 2020;148:135-39.
317. Jonsson M, Berglund E, Djärv T, et al. A brisk walk-Real-life travelling speed of lay responders in out-of-hospital cardiac arrest. *Resuscitation* 2020;151:197-204.
318. Bonnet B, Dessavre D, Kraus K, et al. Optimal placement of public-access AEDs in urban environments. *Comput Ind Eng* 2015;90:269-80.
319. London Ambulance Service NHS Trust (December 2019). *Cardiac Arrest Annual Reprt: 2018/2019*. Available from: <https://www.londonambulance.nhs.uk/download/27269/> [last accessed 19th November 2020].
320. Nilsen P. Making sense of implementation theories, models and frameworks. *Implement Sci* 2015;10:53.
321. Michie S. Making psychological theory useful for implementing evidence based practice: a consensus approach. *Qual Saf Health Care* 2005;14:26-33.
322. Britten N. *Qualitative Interviews*. In: Pope C, Mays N, eds. *Qualitative Research in Health Care*. 3rd ed. Oxford: Blackwell Publishing 2006:12-20.
323. Lewis J, McNaughton Nicholls C. *Design Issues*. In: Ritchie J, Lewis J, McNaughton Nicholls C, et al., eds. *Qualitative Research Practice: A Guide for Social Science Students and Researchers*. 2nd ed. London: SAGE 2014:47-76.
324. Weller S (2015). *The potentials and pitfalls of using Skype for qualitative (longitudinal) interviews*. National Centre for Research Methods; Economic and Social Research Council. Available from: <http://eprints.ncrm.ac.uk/3757/1/Susie%20Weller.pdf> [last accessed 19th November 2020].
325. Shaw S, Wherton J, Vijayaraghavan S, et al. (Nov 2017). *Virtual Online Consultations: Advantages and Limitations (VOCAL)*. A mixed-method study at micro, meso and macro level. Available from: <https://njl-admin.nihr.ac.uk/document/download/2011634> [last accessed 19th November 2020].
326. Seitz S. *Pixilated partnerships, overcoming obstacles in qualitative interviews via Skype: a research note*. *Qual Res* 2016;16:229-35.
327. King N, Horrocks C. *Interviews in Qualitative Research*. London: SAGE 2010.
328. Ericsson KA. *Protocol Analysis and Expert Thought: Concurrent Verbalizations of Thinking during Experts' Performance on Representative Tasks*. In: Ericsson KA,

- Charness N, Feltovich PJ, Hoffman RR, eds. *The Cambridge Handbook of Expertise and Expert Performance*. Cambridge: Cambridge University Press 2006:223-42.
329. van der Haak MJ, De Jong MDT, Schellens PJ. Retrospective vs. concurrent think-aloud protocols: testing the usability of an online library catalogue. *Behav Inf Technol* 2003;22:339-51.
  330. Finch H, Lewis J, Turley C. Focus groups. In: Ritchie J, Lewis J, McNaughton Nicholls C, et al., eds. *Qualitative Research Practice: A Guide for Social Science Students and Researchers*. 2nd ed. London: SAGE 2014:211-42
  331. Heritage J, Robinson JD, Elliott MN, et al. Reducing patients' unmet concerns in primary care: the difference one word can make. *J Gen Intern Med* 2007;22:1429-33.
  332. Mason M. Sample Size and Saturation in PhD Studies Using Qualitative Interviews. *Forum: Qualitative Social Research* 2010;11(3) DOI: <http://dx.doi.org/10.17169/fqs-11.3.1428>
  333. Malterud K, Siersma VD, Guassora AD. Sample Size in Qualitative Interview Studies: Guided by Information Power. *Qual Health Res* 2016;26:1753-60.
  334. Francis JJ, Johnston M, Robertson C, et al. What is an adequate sample size? Operationalising data saturation for theory-based interview studies. *Psychol Health* 2010;25:1229-45.
  335. Møller T, Hansen C, Fjordholt M, et al. Debriefing bystanders of out-of-hospital cardiac arrest is valuable. *Resuscitation* 2014;85:1504-11.
  336. Ericsson KA, Simon HA. *Protocol Analysis: Verbal Reports as Data*. Cambridge, Massachusetts: MIT Press 1993.
  337. Peute LWP, de Keizer NF, Jaspers MWM. The value of Retrospective and Concurrent Think Aloud in formative usability testing of a physician data query tool. *J Biomed Inform* 2015;55:1-10.
  338. Joe J, Chaudhuri S, Le T, et al. The use of think-aloud and instant data analysis in evaluation research: Exemplar and lessons learned. *J Biomed Inform* 2015;56:284-91.
  339. Hamm RM. Theory about heuristic strategies based on verbal protocol analysis: the emperor needs a shave. *Med Decis Making* 2004;24:681-6
  340. Ward P, Suss J, Eccles DW, et al. Skill-based differences in option generation in a complex task: a verbal protocol analysis. *Cogn Process* 2011;12:289-300.
  341. Kuusela H, Paul P. A comparison of concurrent and retrospective verbal protocol analysis. *Am J Psychol* 2000;113:387-404.
  342. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol* 2006;3:77-101.
  343. Tourangeau R, Yan T. Sensitive questions in surveys. *Psychol Bull* 2007;133:859-83.
  344. Michie S, Richardson M, Johnston M, et al. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Ann Behav Med* 2013;46:81-95.
  345. Valenzuela TD, Roe DJ, Cretin S, et al. Estimating effectiveness of cardiac arrest interventions: a logistic regression survival model. *Circulation* 1997;96:3308-13.
  346. Sweller J, Ayres P, Kalyuga S. *Cognitive Load Theory*. New York: Springer 2011.
  347. Niculescu A, Cao Y, Nijholt A. Stress and Cognitive Load in Multimodal Conversational Interactions. In: Stephanides C, ed. *HCI International 13th International Conference on Human-Computer Interaction*. Heidelberg: Springer 2010:891-5.
  348. Conway D, Dick I, Li Z, et al. The Effect of Stress on Cognitive Load Measurement. In: Kotzé P, Marsden G, Lindgaard G, et al., eds. *Human-Computer Interaction – INTERACT 2013*. INTERACT 2013 Lecture Notes in Computer Science, vol 8120. Berlin: Springer 2013.
  349. Ajzen I. The theory of planned behavior. *Organ Behav Hum Decis Process* 1991;50:179-211.
  350. Ericsson K, Krampe R, Tesch-Romer C. The role of deliberate practice in the acquisition of expert performance. *Psychol Rev* 1993;100:363-406
  351. Swor R, Khan I, Domeier R, et al. CPR training and CPR performance: do CPR-trained bystanders perform CPR? *Acad Emerg Med* 2006;13:596-601.
  352. Greif R, Bhanji F, Bigham BL, et al. Education, Implementation, and Teams: 2020 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Resuscitation* 2020;156:A188-A239

353. Skinner B. Operant behavior. In: Science and human behavior. New York: The Free Press 1953:59-90.
354. Axelsson A, Herlitz J, Ekström L, et al. Bystander-initiated cardiopulmonary resuscitation out-of-hospital. A first description of the bystanders and their experiences. *Resuscitation* 1996;33:3-11.
355. Andelius L, Malta Hansen C, Lippert FK, et al. Smartphone Activation of Citizen Responders to Facilitate Defibrillation in Out-of-Hospital Cardiac Arrest. *J Am Coll Cardiol* 2020;76:43-53.
356. Gollwitzer P, Sheeran P. Implementation intentions and goal achievement: a meta-analysis of effects and processes. *Adv Exp Soc Psychol* 2006;38:69-119.
357. Prestwich A, Kellar I. How can the impact of implementation intentions as a behaviour change intervention be improved? *Eur Rev Appl Psychol* 2014;64:35-41.
358. Dolan P, Hallsworth M, Halpern D, et al. (2010). MINDSPACE: Influencing behaviour through public policy. Available from: <https://www.instituteforgovernment.org.uk/sites/default/files/publications/MINDSPACE.pdf> [last accessed 19th November 2020].
359. Flay BR, DiTecco D, Schlegel RP. Mass Media in Health Promotion: An Analysis Using an Extended Information-Processing Model. *Health Educ Q* 1980;7:127-47.
360. Bakker M, Kerstholt J, Giebels E. Deciding to Help: Effects of Risk and Crisis Communication. *J Contingencies Crisis Manag* 2018;26:113-26.
361. Edwards EA, Lumsden J, Rivas C, et al. Gamification for health promotion: systematic review of behaviour change techniques in smartphone apps. *BMJ Open* 2016;6:e012447.
362. Ursin H, Eriksen HR. The cognitive activation theory of stress. *Psychoneuroendocrinology* 2004;29:567-92.
363. Goldsmith JV, Wittenberg E, Ferrell B. An App to Support Difficult Interactions Among Providers, Patients, and Families. *J Adv Pract Oncol* 2015;6:481-5.
364. Riou M, Ball S, Williams TA, et al. 'Tell me exactly what's happened': When linguistic choices affect the efficiency of emergency calls for cardiac arrest. *Resuscitation* 2017;117:58-65.
365. Gudykunst W. An Anxiety/Uncertainty Management (AUM) Theory of Effective Communication: Making the Mesh of the Net Finer. In: Gudykunst W, ed. Theorizing about intercultural communication. New York: Sage 2005:281-322.
366. Mathiesen WT, Bjorshol CA, Hoyland S, et al. Exploring How Lay Rescuers Overcome Barriers to Provide Cardiopulmonary Resuscitation: A Qualitative Study. *Prehosp Disaster Med* 2017;32:27-32.
367. Axelsson A, Herlitz J, Fridlund B. How bystanders perceive their cardiopulmonary resuscitation intervention; a qualitative study. *Resuscitation* 2000;47:71-81.
368. Yeung J, Djarv T, Hsieh MJ, et al. Spaced learning versus massed learning in resuscitation - A systematic review. *Resuscitation* 2020;156:61-71.
369. Magid KH, Ranney ML, Risica PM. Using the theory of planned behavior to understand intentions to perform bystander CPR among college students. *J Am Coll Health* 2019;1-6.
370. Panchal AR, Fishman J, Camp-Rogers T, et al. An "Intention-Focused" paradigm for improving bystander CPR performance. *Resuscitation* 2015;88:48-51.
371. Mausz J, Snobelen P, Tavares W. "Please. Don't. Die.": A Grounded Theory Study of Bystander Cardiopulmonary Resuscitation. *Circ Cardiovasc Qual Outcomes* 2018;11:e004035.
372. Axelsson A, Herlitz J, Karlsson T, et al. Factors surrounding cardiopulmonary resuscitation influencing bystanders' psychological reactions. *Resuscitation* 1998;37:13-20.
373. Mathiesen WT, Bjorshol CA, Braut GS, et al. Reactions and coping strategies in lay rescuers who have provided CPR to out-of-hospital cardiac arrest victims: a qualitative study. *BMJ Open* 2016;6:e010671.
374. Barker F, Atkins L, de Lusignan S. Applying the COM-B behaviour model and behaviour change wheel to develop an intervention to improve hearing-aid use in adult auditory rehabilitation. *Int J Audiol* 2016;55 Suppl 3:S90-8.
375. Cowdell F, Dyson J. How is the theoretical domains framework applied to developing health behaviour interventions? A systematic search and narrative synthesis. *BMC Public Health* 2019;19:1180.

376. Morgan DP, Muscatello D, Hayen A, et al. Human factors influencing out-of-hospital cardiac arrest survival. *Emerg Med Australas* 2019;31:600-4.
377. Michie S, West R, Sheals K, et al. Evaluating the effectiveness of behavior change techniques in health-related behavior: a scoping review of methods used. *Transl Behav Med* 2018;8:212-24.
378. Huijg JM, Gebhardt WA, Crone MR, et al. Discriminant content validity of a theoretical domains framework questionnaire for use in implementation research. *Implement Sci* 2014;9:11.
379. Huijg JM, Gebhardt WA, Dusseldorp E, et al. Measuring determinants of implementation behavior: psychometric properties of a questionnaire based on the theoretical domains framework. *Implement Sci* 2014;9:33.
380. National Institute for Health and Care Excellence (2014). Behaviour changes: individual approaches. Public Health Guideline PH49. Available from: <https://www.nice.org.uk/guidance/ph49> [last accessed 19th November 2020].
381. Cochrane Priority Setting Methods Group (undated). Resources. <https://methods.cochrane.org/prioritysetting/resources> [last accessed 19th November 2020].
382. Wang L, Gan X, Wang X, et al. Does time of day influences outcome in out-of-hospital cardiac arrest patients?: A meta-analysis of cohort studies. *Medicine (Baltimore)* 2020;99:e22290.
383. Bagai A, McNally BF, Al-Khatib SM, et al. Temporal differences in out-of-hospital cardiac arrest incidence and survival. *Circulation* 2013;128:2595-602.
384. El Asmar A, Dakessian A, Bachir R, et al. Out of hospital cardiac arrest outcomes: Impact of weekdays vs weekends admission on survival to hospital discharge. *Resuscitation* 2019;143:29-34.
385. Brooks SC, Schmicker RH, Rea TD, et al. Out-of-hospital cardiac arrest frequency and survival: evidence for temporal variability. *Resuscitation* 2010;81:175-81.
386. Scquizzato T, Pallanch O, Belletti A, et al. Enhancing citizens response to out-of-hospital cardiac arrest: A systematic review of mobile-phone systems to alert citizens as first responders. *Resuscitation* 2020;152:16-25.
387. Wallace SK, Abella BS, Shofer FS, et al. Effect of time of day on prehospital care and outcomes after out-of-hospital cardiac arrest. *Circulation* 2013;127:1591-6.
388. Koike S, Tanabe S, Ogawa T, et al. Effect of time and day of admission on 1-month survival and neurologically favourable 1-month survival in out-of-hospital cardiopulmonary arrest patients. *Resuscitation* 2011;82:863-8.
389. Stieglis R, Zijlstra JA, Riedijk F, et al. AED and text message responders density in residential areas for rapid response in out-of-hospital cardiac arrest. *Resuscitation* 2020;150:170-77.
390. Fukuda T, Ohashi N, Doi K, et al. Impact of seasonal temperature environment on the neurologic prognosis of out-of-hospital cardiac arrest: a nationwide, population-based cohort study. *J Crit Care* 2014;29:840-7.
391. Muller A, Dyson K, Bernard S, et al. Seasonal Variation in Out-of-Hospital Cardiac Arrest in Victoria 2008-2017: Winter Peak. *Prehosp Emerg Care* 2020;24:769-777
392. Rajagopal S, Booth SJ, Brown TP, et al. Data quality and 30-day survival for out-of-hospital cardiac arrest in the UK out-of-hospital cardiac arrest registry: a data linkage study. *BMJ Open* 2017;7:e017784.
393. Sterne JAC, Savović J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ* 2019;366:l4898.
394. Creswell JW, Plano Clark VL. Designing and conducting mixed methods research. 3rd ed. London: SAGE 2018.
395. Haskins B, Smith K, Cameron P, et al. The impact of bystander relation and medical training on out-of-hospital cardiac arrest outcomes. *Resuscitation* 2020;150:72-79.
396. Resuscitation Council UK, British Heart Foundation (November 2015). A consensus statement on AED cabinets. Available from: <https://www.resus.org.uk/defibrillators/cabinets-for-public-access-defibrillators/> [last accessed 19th November 2020].
397. London Ambulance Service NHS Trust (August 2018). Taxi drivers get life-saving training for ambulance pilot scheme. Available from: <https://www.londonambulance.nhs.uk/2018/08/01/taxi-drivers-get-life-saving-training-for-ambulance-pilot-scheme/> [last accessed 19th November 2020].

398. National Institute for Health Research (2019). Funding and Awards. Optimisation of the Deployment of Automatic External Defibrillators in Public Places in England. Available from: <https://fundingawards.nihr.ac.uk/award/NIHR127368> [last accessed 19th November 2020].
399. Perkins GD, Morley PT, Nolan JP, et al. International Liaison Committee on Resuscitation: COVID-19 consensus on science, treatment recommendations and task force insights. *Resuscitation* 2020;151:145-47.
400. Couper K, Taylor-Phillips S, Grove A, et al. COVID-19 in cardiac arrest and infection risk to rescuers: A systematic review. *Resuscitation* 2020;151:59-66.
401. GoodSAM (2020). Instant Help. Ambulance / Police / Fire. Available from: <https://www.goodsamapp.org/instantOnScene> [last accessed 19th November 2020].

# CHAPTER 14

## Appendices

## 14.1 SYSTEMATIC REVIEW (CHAPTER 4)

### 14.1.1 Electronic search strategies

I performed searches on 10<sup>th</sup> March 2017.

MEDLINE:

1. (barrier* or difficult* or imped* or hinder or hindrance* or obstruct* or facilitat* or enabl* or help* or aid* or assist*).m_titl.	421090
2. (availab* or unavailab* or inaccessib* or accessib* or attitude*).m_titl.	187230
3. (opinion* or concern* or knowledge* or confiden* or perception* or willing* or unwilling or intent* or characteristic* or locat* or psychol* or legal* or law*).m_titl.	470434
4. 1 or 2 or 3	1055185
5. Defibrillators/	1406
6. (public access defib* or automated external defib* or automatic external defib*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]	1479
7. 5 or 6	2290
8. 4 and 7	212

EMBASE:

1. (barrier* or difficult* or imped* or hinder or hindrance* or obstruct* or facilitat* or enabl* or help* or aid* or assist*).m_titl.	503184
2. (availab* or unavailab* or inaccessib* or accessib* or attitude*).m_titl.	144733
3. (opinion* or concern* or knowledge* or confiden* or perception* or willing* or unwilling or intent* or characteristic* or locat* or psychol* or legal* or law*).m_titl.	542182
4. 1 or 2 or 3	1161858
5. (public access defib* or automated external defib* or automatic external defib*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]	2762
6. exp automated external defibrillator/	1842
7. 5 or 6	2762
8. 4 and 7	293

### 14.1.2 Data collection form

Data collection table starts on next page, as it appears in the Electronic Supplementary Material in the published article ([111](#)).

Category	Study	Study Design and Key Characteristics	Key Findings
Knowledge and Awareness	Zinckernagel et al 2017 ( <a href="#">263</a> )  Denmark, 2012-2013	Face-to-face semi-structured interviews with 9 school leaders and 1 teacher  Four focus groups with 3-5 teachers from same school in each  Concentrating on opinions of AED deployment and training  Qualitative (thematic) analysis	<b>BARRIER</b> Limited knowledge about where AED at their schools were located and how to access
	Shams et al 2016 ( <a href="#">255</a> )  Beirut, Lebanon, 2015	Self-administered questionnaire to students at one University  91.4% (948/1037) completed questionnaire	<b>BARRIER</b> 33.9% (316/933) knew what an AED was
	Fan et al 2016 ( <a href="#">223</a> )  Hong Kong, 2015	Face-to-face semi-structured questionnaire in public location  54.7% (401/733) completed survey  Survey tool adapted from Brooks et al 2015 ( <a href="#">215</a> )	<b>BARRIER</b> 56.4% (226/401) had heard of AED 35.9% (144/401) knew that prompt AED use increased survival 22.4% (90/401) knew location of nearest AED
	Aagaard et al 2016 ( <a href="#">210</a> )  Copenhagen, Denmark, 2010	1. Face-to-face survey; conducted at international airport 493 respondents, 42 nations Study recognition of ILCOR AED sign  2. Survey of national resuscitation councils	<b>BARRIER</b> 39% recognised AED sign No significant differences in gender, occupation, nationality, age noted
	Brooks et al 2015 ( <a href="#">215</a> )  Southampton, UK, 2014	Face-to-face survey  Public location  1004 respondents	<b>FACILITATOR</b> 69.3% (696/1004) knew what an AED was  <b>BARRIER</b> 26.1% (262/1004) knew how to use an AED 5.1% (51/1004) could locate nearest PAD
	Maes et al 2015 ( <a href="#">238</a> )  Brussels, Belgium, **	1) Survey of AED knowledge  2) Simulated OHCA scenario using manikin and AED directly linked to a call-centre: 2-way audio access activated on removing AED from location	<b>FACILITATOR</b> 84.7% (72/85) of volunteers had 'ever heard of an AED'  <b>BARRIER</b> 29.4% (25/85) of volunteers recognised AED logo

	Volunteers randomly selected from hospital visitors	
Gonzalez et al 2015 ( <a href="#">265</a> ) Pennsylvania, USA, 2013	Face-to-face surveys  Administered at two train stations  Two surveys: one asking about AED unprompted; one showing a picture of an AED and asking about it. Other questions common to both surveys  514 respondents	<b>FACILITATOR</b> 71% had knowledge of AED and its purpose when directly questioned 66.4% recognised AED and its purpose when shown a photo 61.6% aware of publicly available AED  <b>BARRIER</b> 7.9% spontaneously mentioned AED when asked what to do in an OHCA scenario Only 5.3% (14/263) asked about OHCA scenario spontaneously mentioned AED, described how to use it correctly, and indicated willingness to use it in an emergency 39.7% thought anyone could use AED (38.1% thought specific training needed; 9.7% thought medical professionals only could use it)
Taniguchi et al 2014 ( <a href="#">258</a> ) Ishikawa, Japan, 2010	Paper-based survey  High-school students, teachers, nurses, medical students (only results from lay groups presented here)  2527 respondents (response rate not stated)  Follow-up study to Taniguchi et al 2008 ( <a href="#">257</a> )	<b>FACILITATOR</b> 47% of high-school students and 89% of teachers knew what an AED was (significantly higher than in the 2008 paper ( <a href="#">257</a> )).
Kozłowski et al 2013 ( <a href="#">232</a> ) Poland, 2010	Face-to-face survey  Public location  Lay- and BLS/AED-trained groups  404 respondents	<b>BARRIER</b> 31.7% lay group knew what an AED was 22.8% lay group knew when an AED should be used 5.3% lay group knew where the nearest AED could be located
Bogle et al 2013 ( <a href="#">213</a> ) Illinois, USA, 2011	Online survey  University students  267/1000 (26.7%) response rate	<b>FACILITATOR</b> 88.4% identified AED when shown an image  <b>BARRIER</b> 18.4% knew how an AED worked 17.6% knew that university had an AED on site – of which, 2.2% could identify its location
Lee et al 2013 ( <a href="#">266</a> ) South Korea, 2007 and 2011	Comparison of national telephone surveys in 2007 (1029 responses) and 2011 (1000 responses) examining public awareness and attitudes toward bystander CPR	<b>FACILITATOR</b> Awareness of AED increased from 5.8% (60/1029) in 2007 to 30.6% (306/1000) in 2011

	McDonough et al 2012 (267) USA, **	Qualitative study exploring students' (n=30) perceptions about sudden cardiac arrest, including awareness of publicly available AED  Large university, north-eastern USA	<b>BARRIER</b> "One-third" did not know what an AED was 6.7% (2/30) provided 'fairly accurate description' of what an AED was "More than half" did not know whether there were public AED at their university
	Schober et al 2011 (254) Amsterdam, Netherlands, **	Face-to-face surveys  Public location  1018 respondents from 38 nations	<b>BARRIER</b> Only 6% respondents spontaneously mentioned AED / defibrillation as treatment option if someone had a cardiac arrest in front of them 43% aware that AED were available for public access in certain locations 47% correctly identified AED when shown the device in person; 53% knew its purpose  Beliefs about who can use AED - Anyone: 34% - Trained personnel only: 49% - Healthcare professionals only: 13%
	Sneath et al 2009 (256) 'South-eastern' USA, **	Written survey  Convenience sample, industrial park Previously identified as potential site for PAD programme  78/100 (78.0%) response rate	<b>FACILITATOR</b> 60% aware of what an AED was  <b>BARRIER</b> <10% of businesses had an AED; 21% trained in AED use 40% thought it would be 'extremely difficult' or 'somewhat difficult' to use AED
	Taniguchi et al 2008 (257) Ishikawa, Japan, 2006	Paper-based survey  High-school students, teachers, nurses, medical students (only results from lay groups presented here)  3328/3500 (95.1%) response rate	<b>BARRIER</b> 15% high-school students and 44% of teachers knew what an AED was
	Kuramoto et al 2008 (233) Japan, 2006	Face-to-face survey; home visit  1132/2400 (47%) participated	<b>BARRIER</b> 12% (134/1132) aware that AED are available in public 17% (197/1132) know how to use an AED 19% (214/1132) know that laypeople can use AED in public places
<b>Willingness to Use</b>	Zinckernagel et al 2017 (263) Denmark, 2012-2013	Face-to-face semi-structured interviews with 9 school leaders and 1 teacher  Four focus groups with 3-5 teachers from same school in each  Concentrating on opinions of AED deployment and training  Qualitative (thematic) analysis	<b>FACILITATOR</b> Natural that AED should be part of CPR training to students Increasing profile / visibility of AED made it more relevant to learn about them AED training perceived as beneficial and would improve use  <b>BARRIER</b> Most felt uncomfortable using AED without training, and expected training to be necessary Felt AED could be dangerous and cause more harm than good in some circumstances

			Unease about being able / expected to deliver AED training
Shams et al 2016 ( <a href="#">255</a> ) Beirut, Lebanon, 2015	Self-administered questionnaire to students at one University  91.4% (948/1037) completed questionnaire		<b>FACILITATOR</b> 87.8% (818/932) believed that bystanders (including themselves) should learn CPR/AED  <b>BARRIER</b> 16.3% (147/904) would be confident using an AED
Fan et al 2016 ( <a href="#">223</a> ) Hong Kong, 2015	Face-to-face semi-structured questionnaire in public location  54.7% (401/733) completed survey  Survey tool adapted from Brooks et al 2015 <sup>36</sup>		<b>BARRIER</b> 29.7% (119/401) would try and locate AED 18.0% (72/401) would apply an AED if available
Brooks et al 2015 ( <a href="#">215</a> ) Southampton, UK, 2014	Face-to-face survey  Public location  1004 respondents		<b>BARRIER</b> 3.3% (33/1004) would retrieve AED for OHCA 2.1% (21/1004) would retrieve <i>and use</i> AED for OHCA
Maes et al 2015 ( <a href="#">238</a> ) Brussels, Belgium, **	1) Survey of AED knowledge  2) Simulated OHCA scenario using manikin and AED directly linked to a call-centre: 2-way audio access activated on removing AED from location  Volunteers randomly selected from hospital visitors		<b>BARRIER</b> 40.0% (34/85) of volunteers felt able to use an AED. Of those that did not: - 45% didn't know how device worked - 4% would feel too stressed - 2% afraid of causing harm to victim
Gonzalez et al 2015 ( <a href="#">265</a> ) Pennsylvania, USA, 2013	Face-to-face surveys Administered at two train stations  Two surveys: one asking about AED unprompted; one showing a picture of an AED and asking about it. Other questions common to both surveys  514 respondents		<b>FACILITATOR</b> 58.1% willing to use AED in medical emergency
Taniguchi et al 2014 ( <a href="#">258</a> ) Ishikawa, Japan, 2010	Paper-based survey  High-school students, teachers, nurses, medical students (only results from lay groups presented here)  2527 respondents (response rate not stated)		<b>FACILITATOR</b> 73% high-school students and 87% of teachers would "definitely" use AED if required  <b>BARRIER</b> Amongst those unwilling to use an AED: - 85% because they did not know what one was / how to use it

	Follow-up study to Taniguchi et al 2008 (258)	<ul style="list-style-type: none"> <li>- 25% because they thought that chest compressions had to be performed before an AED could be used</li> <li>- 8% (all teachers) declined to operate AED because of fears of legal liability</li> </ul>
Kozłowski et al 2013 (232) Poland, 2010	Face-to-face survey Public location Lay- and BLS/AED-trained groups 404 respondents	<b>BARRIER</b> 25.4% lay group would use an AED for SCA; 57.8% undecided; 16.4% would not use AED (does not equal 100%, not explained) Of lay group who would not use AED: 40.2% because they did not know how to use it, 24.7% because of fear of using it incorrectly, 2.7% fear of consequences
Bogle et al 2013 (213) Illinois, USA, 2011	Online survey University students 267/1000 (26.7%) response rate	<b>BARRIER</b> 28.1% comfortable using an AED without assistance Primary reason for fear of using an AED: <ul style="list-style-type: none"> <li>- Afraid to do something wrong: 87.7%</li> <li>- Could be of better use in other ways: 4.8%</li> <li>- Fear of being sued: 4.1%</li> </ul>
Nielsen et al 2013a (244) Bornholm Island, Denmark, 2008-2009	Before (2008)-and-after (2009) study Investigating effect of mass education and media campaign on CPR attitudes Telephone survey 2008: 849/1180 (71.9%) response rate 2009: 838/1154 (72.5%) response rate	<b>FACILITATOR</b> 2009: 65% "definitely willing to use AED on a stranger" 2008: 44% definitely willing to use AED on a stranger  <b>BARRIER</b> Reasons for not using AED <ul style="list-style-type: none"> <li>- 'Don't know to operate one ' (77% in 2008, 62% in 2009)</li> <li>- 'Don't know what it is ' (11% vs 5%),</li> <li>- 'Afraid of doing harm ' (6% vs 9%)</li> <li>- Other (4% vs 22%)</li> </ul>
McDonough et al 2012 (267) USA, **	Qualitative study exploring students' (n=30) perceptions about sudden cardiac arrest, including awareness of publicly available AED Large university, north-eastern USA	<b>BARRIER</b> The main themes relating to AED use were 'uncertainty' and 'fear/uncomfortableness' at the use of AED in an OHCA "Most" participants would rather wait for someone who was more comfortable in the use of AED, "in order to avoid causing more harm".
Schober et al 2011 (254) Amsterdam, Netherlands, **	Face-to-face surveys Public location 1018 respondents from 38 nations	<b>BARRIER</b> 47% willing to use an AED Reasons for not using an AED <ul style="list-style-type: none"> <li>- No knowledge of how it works: 69%</li> <li>- Concerns about harming the victim: 14%</li> <li>- Legal concerns: 5%</li> </ul>
McDonald et al 2010 (239) Connecticut, USA, **	Randomised controlled trial Control arm: Given leaflet encouraging them to learn CPR and AED	<b>FACILITATOR</b> For the outcome "In the next 3 months I plan to routinely check for the location of public access defibrillators" significantly more people in the intervention arm compared to the control arm planned to do this (50/95, 52.6% vs 41/110, 37.3%, p < 0.03)

	<p>Intervention arm: same leaflet, with addition of two motivational messages:  1) learn CPR "to save someone you love"  2) Initiate CPR and AED "within 1-3 minutes and "do not wait"</p> <p>Participants had no prior experience with CPR / AED</p>	<p><b>NEUTRAL</b>  For the outcome "In the next 3 months I plan to take a class in CPR and use of automatic external defibrillator (AED)" there was no difference between intervention-and control arms (38/95, 40.4% vs 39/110, 35.5%, p = ns)</p>
<p>Sneath et al 2009 (<u>256</u>)  'South-eastern' USA, **</p>	<p>Written survey  Convenience sample, industrial park  Previously identified as potential site for PAD programme</p> <p>78/100 (78.0%) response rate</p>	<p><b>FACILITATOR</b>  79% willing to use AED to save a life</p>
<p>Kuramoto et al 2008 (<u>233</u>)  Japan, 2006</p>	<p>Face-to-face survey; home visit  1132/2400 (47%) participated</p>	<p><b>BARRIER</b>  9% (100/1132) can use AED without hesitation</p>
<p>Taniguchi et al 2008 (<u>258</u>)  Ishikawa, Japan, 2006</p>	<p>Paper-based survey  High-school students, teachers, nurses, medical students (only results from lay groups presented here)</p> <p>3328/3500 (95.1%) response rate</p>	<p><b>BARRIER</b>  12% high-school students and 35% of teachers would "definitely" use AED if required  Amongst those unwilling to use an AED:  - 70% because they did not know what one was / how to use it  - 20% because they thought that chest compressions were more important  - 5% (all teachers) declined to operate AED because of fears of legal liability</p>
<p>Harrison-Paul et al 2006 (<u>228</u>)  England, 2003-2004</p>	<p>53 Qualitative Interviews; 9 with AED trainers, 44 with laypeople trained in AED use (many of whom had used AED in real-life)  From organisations that had AED provided under the 'Defibrillators in Public Places' scheme</p>	<p><b>BARRIER</b>  Hesitation from respondents to take AED and use it in a different area to that which they would usually oversee; lack of clarity about their responsibility and potential liability in such situations</p>
<p>Lubin et al 2004 (<u>237</u>)  USA, 2001</p>	<p>Face-to-face survey  Public location  359 respondents</p>	<p><b>FACILITATOR</b>  71.3% willing to use an AED on a stranger "whose heart had stopped"  Willingness to use AED increased from 71.3% to 83.1% if respondents informed about legal liability protection afforded under the Cardiac Arrest Survival Act 2000</p> <p><b>BARRIER</b>  Reasons for not using AED:  - Fear of using machine incorrectly: 57%  - Fear of legal liability: 38%  - Unwilling to remove shirt to apply: 24% overall, 28% if female victim</p>

	Hubble et al 2003 ( <u>231</u> ) North Carolina, USA, **	Paper survey Administered after students shown video on AED operation, then six video OHCA scenarios 685 high-school students	<b>BARRIER</b> Willing to use AED on 32.0% (1308/4098) occasions (total number of scenario viewings) Reasons for not using an AED - Fear of injuring the patient: 31.3% - Fear of legal consequences: 16.9% - Fear of infection: 10.5% - Fear of injury to self: 9.5%
<b>Acquisition and Maintenance</b>	Yoon et al 2016 ( <u>261</u> ) Busan City, South Korea, 2013	Observational study Prospective data collection about AED sites and maintenance Confirmed 206 AED	<b>FACILITATOR</b> 99.5% (205/206) AED were operable
	Timmons et al 2014 ( <u>260</u> ) England, 2011-2012	Semi-structured interviews with 15 people from 5 English Universities; who would have involvement in decisions relating to AED acquisition	<b>FACILITATOR</b> Influential in decisions to acquire AED: - Trade union representation - Previous cardiac arrest on site influential AED seen as effective and 'expert' way of mitigating cardiac arrest risk  <b>BARRIER</b> None mentioned media campaigns or representations by local ambulance service as reasons for AED acquisition
	Nielsen et al 2013b ( <u>243</u> ) Denmark, 2010-2011	Observational study Reviewing use of 807 AED (from one manufacturer) in Denmark	<b>FACILITATOR</b> 68% of 807 AED were donated, rather than purchased
	Cronin et al 2013 ( <u>218</u> ) Ireland, 2012	Telephone survey Amateur Gaelic Athletic Association (GAA), soccer and rugby clubs 171/218 (78.4%) response rate	<b>FACILITATOR</b> 81.3% (139/171) clubs owned an AED 98.6% (137/139) had someone trained in AED use Obtained via: - Fundraising: 36.7% (51/139) - Donation: 20.9% (29/139) - Own purchase: 12.9% (18/139)  <b>BARRIER</b> Less than half games / training sessions had an AED-trained individual present 23.7% (33/139) clubs did not maintain AED / did not know In cases where clubs did not own an AED: - Cost: 37.5% (12/32) - Other reasons: nobody trained to use, not a priority, nobody to maintain, nearby AED in locality, medicolegal fears (percentages / numbers not stated)

<p>Ashimi et al 2010 (<u>211</u>)</p> <p>Scotland, **</p>	<p>Written survey</p> <p>Sent to public places with “sufficiently high footfall to justify location of a defibrillator”</p> <p>153/183 (83.7%) response rate</p>	<p><b>FACILITATOR</b></p> <p>21.6% (33/153) sites had <math>\geq 1</math> AED:</p> <ul style="list-style-type: none"> <li>- 96.7% (32/33) sites with AED had provided staff training</li> <li>- 87.9% (29/33) sites provided re-training; median interval one year</li> </ul> <p><b>BARRIER</b></p> <ul style="list-style-type: none"> <li>- 18.2% (6/33) sites had written maintenance agreement for AED</li> <li>- 24.2% (8/33) sites had replacement policy for AED</li> </ul>
<p>Haskell et al 2009 (<u>230</u>)</p> <p>USA, 2006</p>	<p>Written survey</p> <p>Analysis of PAD sites and compliance with American Heart Association (AHA) guidelines for PAD sites</p> <p>32/33 (97.0%) response rate</p>	<p><b>BARRIER</b></p> <p>None compliant with all of AHA recommendations</p> <p>Mean 57% compliance with AHA recommendations overall</p> <p>Mean 64% compliance with AHA recommendations relating to maintenance and planning</p>
<p>Richardson et al 2005 (<u>250</u>)</p> <p>USA and Canada, 2000-2003</p>	<p>Qualitative study</p> <p>Analysis from the North American PAD Trial</p>	<p><b>BARRIER</b></p> <p>Recruitment and implementation problems (of trained volunteers to respond with CPR/AED in case of OHCA):</p> <ul style="list-style-type: none"> <li>- Identifying appropriate decision maker in ‘unit’ (physical location / building)</li> <li>- Fear of litigation</li> <li>- Lack of available volunteers</li> <li>- Volunteers not attending training</li> <li>- Lack of existing emergency medical response plan in unit</li> </ul> <p>36% attrition rate in volunteers in first two years</p>
<p>Bartimus et al 2004 (<u>212</u>)</p> <p>Washington State, USA, 2003</p>	<p>Written survey, to sites previously identified as high-risk for OHCA</p> <p>228/263 (86.7%) response rate</p>	<p><b>BARRIER</b></p> <p>9.9% (14/141) sites without AED had never heard of AED</p> <p>13.5% (19/141) with plans to purchase AED</p> <p>Remaining 108 sites; reasons not to purchase:</p> <ul style="list-style-type: none"> <li>- Cost: 44.4% (48/108)</li> <li>- Not considered: 24.1% (26/108)</li> <li>- “No need”: 13.0% (14/108)</li> <li>- Liability concerns: 7.4% (8/108)</li> <li>- Nearby fire dept or hospital: 11.1% (12/108)</li> </ul>
<p>Coris et al 2004 (<u>217</u>)</p> <p>USA, 2002</p>	<p>Written survey</p> <p>National Collegiate Athletic Association Division 1 athletic departments</p> <p>Response rate 61.4% (186/303)</p>	<p><b>FACILITATOR</b></p> <p>AED unit being donated, or perceived medical benefit to AED ownership predictors of AED acquisition in logistic regression model</p> <p>Reasons cited as influence to obtain AED:</p> <ul style="list-style-type: none"> <li>- Affordability: 54.8% (102/186)</li> <li>- Liability concerns: 51.1% (95/186)</li> <li>- Medical benefit: 29.0% (54/186)</li> </ul> <p><b>BARRIER</b></p>

			<p>Reasons for decision not to obtain AED:</p> <ul style="list-style-type: none"> <li>- Liability concerns: 36.5% (31/85)</li> <li>- No deaths at institution or nearby institutions: 34.1% (29/85)</li> <li>- Good EMS response locally: 32.9% (28/85)</li> <li>- Too expensive: 31.8% (27/85)</li> </ul>
<b>Availability and Accessibility</b>	Sun et al 2016 ( <u>179</u> ) Toronto, Canada, 2006-2014	<p>Observational study</p> <p>Retrospective review of public location, non-traumatic OHCA (2440 cases)</p> <p>Record of registered AED placement</p>	<p><b>BARRIER</b></p> <p>18.5% (451/2440) public OHCA occurred within 100m of an AED</p> <p>14.5% (354/2440) occurred within 100m of an AED that was available at that time of day (a reduction of 21.5%)</p> <p>Four location types accounted for the largest loss of AED coverage out-of-hours and housed 63.9% of AED (schools, industrial facilities, sports facilities, offices)</p>
	Chrisinger et al 2016 ( <u>216</u> ) Philadelphia, USA (one downtown region only)	<p>Observational study</p> <p>Mapping of 295 AED locations</p> <p>Mapping of OHCA risk by location type (estimates from previous epidemiological data (<u>214</u>)) using two different methods</p>	<p><b>FACILITATOR</b></p> <p>AED within 3-min and 6-min response radii of 56.0% and 79.9% land areas, respectively</p> <p>70.1% - 79.8% of OHCA risk covered within 3-min response distance of AED</p> <p>91.5% - 98.1% of OHCA risk covered within 6-min response distance of AED</p>
	Yoon et al 2016 ( <u>261</u> ) Busan City, South Korea, 2013	<p>Observational study</p> <p>Prospective data collection about AED sites and maintenance</p> <p>Confirmed 206 AED</p>	<p><b>FACILITATOR</b></p> <p>58.7% (121/206) AED were stored in an accessible location</p>
	Lin et al 2016 ( <u>236</u> ) Kaohsiung, Taiwan, 2011-2013	<p>Observational study</p> <p>Retrospective data review</p> <p>Mapped 6135 OHCA and 476 AED</p> <p>Use mathematical modelling techniques to determine demand (i.e. occurrence of OHCA at a location) and supply of AED</p>	<p><b>BARRIER</b></p> <p>Supply of AED is less than the demand in "majority of areas" (described and displayed graphically, not enumerated). Assumed AED-coverage of 200m.</p>
	Fredman et al 2016 ( <u>180</u> ) Stockholm, Sweden, 2014	<p>Observational study</p> <p>Prospective review of call recordings identified as 'potential OHCA'</p>	<p><b>BARRIER</b></p> <p>6.6% (200/3009) OHCA occurred within 100m of AED</p> <p>AED was available for use in 23.5% (47/200) of cases</p>
	Griffis et al 2016 ( <u>225</u> ) Philadelphia, USA, **	<p>Observational study</p> <p>Registry review of AED locations</p>	<p><b>BARRIER</b></p> <p>9.5% (4/42) areas (ZIP codes) had &gt;65% AED coverage</p> <p>28.6% (12/42) areas had &lt;35% AED coverage</p>

		AED coverage defined as 400m radius around AED	
Moon et al 2015 ( <u>241</u> ) Arizona, USA, 2010-2012	Observational study Registry review of <b>public location</b> OHCA and AED		<b>BARRIER</b> Weak correlation overall between public OHCA location and PAD placement (Spearman's Rank = 0.283) Discrepancies include: - No AED in most common (29.1% total) public OHCA location (cars/roads/parking lots) - 38.9% (663/1704) AED in businesses for 9.9% (65/654) of total OHCA - 32.8% (558/1704) AED in schools for 0.8% (5/654) of total OHCA
Agerskov et al 2015 ( <u>176</u> ) Copenhagen, Denmark, 2011-2013	Observational study Investigating AED deployment in OHCA occurring within 100m of a known AED Data collected from online network linked to EMS/dispatch		<b>BARRIER</b> 23.4% (102/436) of OHCA occurred within 100m of AED AED available for use in 15.1% (66/436) OHCA AED attached in 30.3% (20/66) cases when it was available (6 after referral by EMS Dispatch)
Ho et al 2014 ( <u>177</u> ) New Territories West, Hong Kong, 2010-2013	Observational study Registry review of OHCA location Manual identification of AED Geographical mapping of OHCA / AED locations		<b>BARRIER</b> 25.2% (548/1785) OHCA occurred within 100m of an AED Of these, 0.55% (3/548) received PAD by a bystander (or 0.17%, 3/1785 total OHCA)
Huig et al 2014 ( <u>197</u> ) Netherlands, 2012	Written questionnaire to identify AED Visual inspection of AED made Comparable shopping areas of city centre regions of six cities identified Weekdays only		<b>FACILITATOR</b> Trained user present for 98% (120/122) AED; 93% (118/122) for all of business hours  <b>BARRIER</b> 70% AED were considered available for use: 40% (49/122) AED not visible 29% (36/122) AED not indicated with sign 16% (19/122) defibrillator pads had expired 7% (8/122) had empty battery
Hansen et al 2014 ( <u>227</u> ) Copenhagen, Denmark, 2007-2011	Observational Study Overlaps with dataset used in Hansen et al 2013 ( <u>181</u> ) Temporal trends in OHCA coverage by PAD after establishing PAD network in 2007		<b>FACILITATOR</b> From 2007-2011: - AED numbers increased from 36 to 552 - AED numbers increased in high-risk areas (defined as one cardiac arrest every two years) from 1 to 30 - AED coverage (historical OHCA in time period occurring <100m of currently placed AED) increased from 2.7% (51/1864) to 32.6% (608/1864); from 5.7% (n=19) to 51.3% (n=172) in high-risk areas  <b>BARRIER</b> From 2007-2011:

			<ul style="list-style-type: none"> <li>- Only 55 <i>actual</i> OHCA occurred within 100m of an accessible AED</li> <li>- Only 9 OHCA had AED applied before arrival of EMS; 8 were defibrillated</li> <li>- Most AED placed in areas of low risk (57.6%, 318/552) for OHCA or in areas where no OHCA had occurred (37.0%, 204/552) (1994-2011)</li> </ul>
Cronin et al 2013 (218)	Telephone survey	Amateur Gaelic Athletic Association (GAA), soccer and rugby clubs	<b>BARRIER</b> AED in "very accessible" location in 51.1% (69/135) clubs AED locked in 59.7 (83/139) clubs
Ireland, 2012	171/218 (78.4%) response rate		
Hansen et al 2013 (181)	Observational study	Analysis of AED coverage of OHCA – looks at <i>potential</i> for AED use	<b>BARRIER</b> AED coverage (historical OHCA in time period occurring <100m of currently placed AED) was 28.8% (537/1864) 9.1% (50/552) registered AED available at all hours Inaccessibility of AED reduced coverage of OHCA by: <ul style="list-style-type: none"> <li>- 33.5% (180/537) overall</li> <li>- 4.1% (9 of 217 OHCA) during daytime (0800 to 1559hrs)</li> <li>- 53.4% (171/320) during evening, nights and weekends</li> </ul>
Copenhagen, Denmark, 1994-2011			
Chan et al 2013 (178)	Observational study	Registry review of OHCA and AED	<b>BARRIER</b> 23.2% (304/1310) <i>public location</i> OHCA occurred within 100m of an AED Average distance to closest AED was 281m
Toronto, Canada, 2005-2010	Geographical mapping of OHCA / AED locations		
Brooks et al 2013 (214)	Observational study	Registry Review of OHCA and AED	<b>BARRIER</b> Mismatch between OHCA location and AED placement Top 5 sites for AED locations were ranked 13 <sup>th</sup> /26 <sup>th</sup> /15 <sup>th</sup> /31 <sup>st</sup> /2 <sup>nd</sup> for incidence of OHCA) Table 3 gives more information
Toronto, Canada, 2006-2010	Compares OHCA and AED location		
Leung et al 2013 (234)	Observational study	Attempt to enumerate and locate AED in a high-employment area	<b>BARRIER</b> 283 AED in 12% (115/967) accessible buildings 81 AED visualised (others photographed or were not allowed to see), of which: <ul style="list-style-type: none"> <li>- 34.6% (28/81) were not readily visible</li> <li>- 21.0% (17/81) were in partially obstructed locations</li> </ul> Getting information about AED from workers difficult: <ul style="list-style-type: none"> <li>- Mean 4 minutes to confirm presence / absence of AED (range 1-55 minutes)</li> <li>- Median 2 people contacted per building with an AED to confirm its presence</li> </ul>
Philadelphia, USA, 2011			
Levy et al 2013 (235)	Observational study	Registry Review of OHCA and AED	<b>BARRIER</b> Weak correlation between OHCA location and PAD placement ( $r^2 = 0.051$ ) None of top 5 sites for OHCA incidence had AED
Maryland, USA, 2001-2006	Comparing OHCA and AED location		
Ashimi et al 2010 (211)	Written survey		<b>BARRIER</b> 21.6% (33/153) sites had $\geq 1$ AED:

	Scotland, **	Sent to public places with “sufficiently high footfall to justify location of a defibrillator”  153/183 (83.7%) response rate	- AED in 18.2% (6/33) sites were in areas accessible to the general public - AED in 3.0% (1/33) sites could actually be used by a member of the public
	Ringh et al 2009 ( <u>251</u> )  Sweden, 1992-2005	Observational study  Registry Review of OHCA  Identified OHCA occurring in suitable sites for PAD placement	<b>BARRIER</b> 26.2% (10133/38710 OHCA) deemed suitable for PAD (occurring outside home, excluding EMS-witnessed cases)
	Peberdy et al 2006 ( <u>246</u> )  USA and Canada, 2000-2003	Observational study  Review of adverse events from the North American PAD Trial	<b>FACILITATOR</b> <b>Very few</b> AED-related adverse events in the study: - 1.2% (20/1716) devices stolen - 0.17% (3/1716) occasions AED moved to location not known to first responder - 0.17% (3/1716) AED inappropriately maintained
	Ragin et al 2005 ( <u>248</u> )  New York, USA, 2000-2003	Observational study  Analysis of one site from the North American PAD Trial	<b>BARRIER</b> In 33 residential ‘units’ (physical locations/buildings), the PAD response system was activated in 24.5% (24/98) cases of OHCA during the trial period
	Engdahl et al 2005 ( <u>222</u> )  Gothenberg, Sweden, 1994-2002	Observational study  Registry Review of OHCA  Identified OHCA occurring in suitable sites for PAD placement	<b>BARRIER</b> 17% (372/2179) of OHCA occurring in sites deemed suitable for PAD (public locations, defined in Table 2)
	Pell et al 2002 ( <u>247</u> )  Scotland, 1991-1998	Observational study  Registry Review of OHCA  Identified OHCA occurring in suitable sites for PAD placement	<b>BARRIER</b> 18.0% (2732/15189) OHCA occurred in sites deemed suitable for PAD (public locations, defined in Table 1)
<b>Training Issues</b>	Fan et al 2016 ( <u>223</u> )  Hong Kong, 2015	Face-to-face semi-structured questionnaire in public location  54.7% (401/733) completed survey  Survey tool adapted from Brooks et al 2015 ( <u>215</u> )	<b>FACILITATOR</b> Significantly more people with previous first aid training (compared to untrained): knew what an AED was (76.6% vs 45.8%) and that prompt use increased survive (52.6% vs 27.3%), knew location of nearest AED (39.4% vs 13.6%) would locate AED (53.3% vs 17.4%), use an AED if available (41.6% vs 5.7%).  <b>BARRIER</b> 34.2% (137/401) had previous first aid training 85.3% (342/401) had no training in use of AED

Brooks et al 2015 ( <a href="#">215</a> ) Southampton, UK, 2014	Face-to-face survey Public location 1004 respondents	<b>FACILITATOR</b> 7.0% (43/613) with first-aid training vs 2.0% without (8/391) could locate nearest PAD 5.2% (32/613) with first-aid training vs 0.3% (1/391) without would retrieve AED for OHCA 3.3% (20/613) with first-aid training vs 0.3% (1/391) without would retrieve <i>and</i> use AED for OHCA
Kozłowski et al 2013 ( <a href="#">232</a> ) Poland, 2010	Face-to-face survey Public location Lay- and BLS/AED-trained groups 404 respondents	<b>FACILITATOR</b> 84.4% with prior BLS-AED training (working at site where survey was carried out) vs 5.3% lay group knew where the nearest AED could be located. 78.9% vs 22.8% when an AED should be used 35.0% vs 25.4% would use an AED during a resuscitation
Bogle et al 2013 ( <a href="#">213</a> ) Illinois, USA, 2011	Online survey University students 267/1000 (26.7%) response rate	<b>FACILITATOR</b> Comfort in using AED (trained in BLS/AED vs trained in BLS only) - Without assistance: 60.8% vs 20.4% - With 9-1-1 assistance 82.3% vs 66.4% (95% CI overlap)  Comfort in using AED (Formal recent training vs no training) – see <i>Table 6 for more details</i> - Without assistance: 50.0% vs 13.9% - With 9-1-1 assistance 84.8% vs 47.7%
Ong et al 2013 ( <a href="#">245</a> ) Singapore, 2009-2010	Face-to-face interviews (visiting lay public unannounced at home) 4192 respondents (62.5% response rate)	<b>BARRIER</b> Fewer had received AED training (10.7%), compared to CPR: 31.4% (1315/4192) Fewer held valid AED training certificates (3.7%), compared to CPR: 9.6% (401/4192)
Enami et al 2011 ( <a href="#">264</a> ) Ishikawa prefecture, Japan, 2007-2009	Written survey to participants of BLS courses and safe-driving courses Analysed 87.5% (22692/25922) surveys Four scenarios, one including AED use	<b>FACILITATOR</b> Significant predictors of willingness to use AED were - Knowing how to use AED in the under 60s (90.7% vs 42.2% who did not) and over 60s (86.6% vs 23.6%) - Previous BLS training in the under 60s (74.9% 3+ times vs 70.2% twice vs 59.4% once vs 48.0% never) and over 60s (51.5% 3+ times vs 38.1% twice vs 32.7% once vs 17.3% never)
Sneath et al 2009 ( <a href="#">256</a> ) 'South-eastern' USA, **	Written survey Convenience sample, industrial park Previously identified as potential site for PAD programme 78/100 (78.0%) response rate	<b>FACILITATOR</b> Greater willingness to use AED would occur if there was (most common responses): - Greater knowledge and training: 13.2% - Easy/simple instructions: 9%  Prior AED training increased comfort level in performing CPR on colleagues and strangers  <b>NEUTRAL</b>

			<p>Prior AED training did not increase comfort level in performing CPR on relatives and friend</p> <p><b>BARRIER</b> 35% willing to spend &gt;4 hours in training</p>
	<p>Groh et al 2007 (226)</p> <p>USA and Canada, 2000-2003</p>	<p>Observational study</p> <p>Analysis of the North American PAD Trial</p>	<p><b>FACILITATOR</b> Volunteers responding to at least one medical emergency, compared to those that did not, were:</p> <ul style="list-style-type: none"> <li>- <b>More likely</b> to have undertaken pre-trial CPR training: 77.3% vs 57.9%</li> <li>- <b>More likely</b> to have undertaken follow-up AED skills testing: 73.1% vs 49.5%</li> </ul> <p><b>NEUTRAL</b> Volunteers responding to at least one medical emergency, compared to those that did not, were <b>no more likely</b> to have passed follow-up AED skills testing: 88% vs 90.7%</p>
	<p>Harrison-Paul et al 2006 (228)</p> <p>England, 2003-2004</p>	<p>53 Qualitative Interviews; 9 with AED trainers, 44 with laypeople trained in AED use (many of whom had used AED in real-life)</p> <p>From organisations that had AED provided under the 'Defibrillators in Public Places' scheme</p>	<p><b>BARRIER</b> Classroom-based training scenarios felt to be less useful than in-situ scenarios would be in preparation them for real-life incidents using AED</p>
	<p>Lubin et al 2004 (237)</p> <p>USA, 2001</p>	<p>Face-to-face survey</p> <p>Public location</p> <p>359 respondents</p>	<p><b>FACILITATOR</b> Willingness to use AED increased from 71.3% to 90.6% if respondents offered training</p>
	<p>Hubble et al 2003 (231)</p> <p>North Carolina, USA, **</p>	<p>Paper survey</p> <p>Administered after students shown video on AED operation, then six video OHCA scenarios</p> <p>685 high-school students</p>	<p><b>NEUTRAL</b> Previously witnessing cardiac arrest: no effect on willingness to use AED Prior training in AED: no effect on willingness to use AED</p>
	<p>Meischke et al 2002 (240)</p> <p>Washington state, USA, **</p>	<p>Written survey</p> <p>Immediately after re-training in AED use (initial training 3 months previously)</p> <p>159 respondents</p> <p>"Seniors" (mean age 71.3 years)</p>	<p><b>FACILITATOR</b> Intention to use AED positively associated with:</p> <ul style="list-style-type: none"> <li>- Successful use of AED in training scenario</li> <li>- Greater self-perceived efficacy in using AED</li> </ul>
<b>Registration and Regulation</b>	<p>Ringh et al 2015 (136)</p>	<p>Observational study</p>	<p><b>BARRIER</b> Only 28.4% (21/74) OHCA victims defibrillated by AED registered in SALSA-PAD programme, 71.6% (53/74) by 'unregulated' AED.</p>

	Stockholm, Sweden, 2006-2012	Comparison of PAD with AED registered to city's 'SALSA' PAD programme), versus 'unregulated' AED	<b>NEUTRAL</b> Survival 71.4% with AED from SALSA-PAD, 69.8% with unregulated AED (p=ns)
	Rea et al 2011 (249) Washington state, USA, 2007-2009	Observational study  Retrospective review of OHCA for which EMS were dispatched	<b>BARRIER</b> In 22 cases of AED use by lay public: 9 AED known to EMS Dispatch, 13 not previously registered. This is in a US state where AED registration is mandated by law
	Myers et al 2005 (242) North Carolina, USA, 2001-2002	Mixed methods  EMS database review; survey of EMS representatives, AED sales representatives and AED trainers  To determine how many AED were registered with EMS	<b>BARRIER</b> Only 17.9% (99/552) PAD locations identified were known to EMS
<b>Medicolegal Issues</b>	Gilchrist et al 2012 (224)  USA, 2010	Document review of laws relating to PAD and AED in US jurisdictions (50 states and Washington D.C)  Description of which of 13 elements of PAD programmes (as recommended by AHA) are mandated by law	<b>BARRIER</b> No jurisdiction mandated all 13 elements; median number of 6 elements required 18% required 10 or more elements 31.4% (16/51) required 3 or fewer elements Civil immunity for rescuers explicitly mentioned in law in 80.3% (41/51) jurisdictions Quality improvement arrangements explicitly mentioned in 25.4% (13/51) jurisdictions  See Table in article for more information
<b>EMS Dispatch-assisted AED use</b>	Fredman et al 2016 (180)  Stockholm, Sweden, 2014	Prospective observational study  Review of call recordings identified as 'potential OHCA'	<b>BARRIER</b> EMS dispatcher referred caller to AED in 4.3% (2/47) cases where AED was available ≤ 100m; or 1.0% (2/200) OHCA where AED present within 100m; or 0.07% (2/3009) total OHCA. No reason for EMS non-referral identified in more than 50% of cases
	Pijls et al 2016 (164)  Limburg, Netherlands, 2012-2014	Observational study  Retrospective review of 833 OHCA of presumed cardiac origin  Volunteer responders activated by EMS dispatchers via text-message in 50.7% (422/833) cases  Volunteer attended on-scene in 34.9% (291/833) cases	<b>FACILITATOR</b> Text-message responders were first to connect AED in 26.8% (78/291) cases where one attended; 18.5% (78/833) of cases where the system was activated and 9.4% (78/833) cases overall
	Riyapan et al 2016 (252)	Simulation RCT	<b>FACILITATOR</b>

Pennsylvania, USA, **	OHCA in shopping mall; both groups had simulated conversation with 'dispatcher' and asked to retrieve AED  Intervention group: given specific directions to locate nearest AED Control group: no directions given	In the intervention group, there were significant reductions in: - Time to AED retrieval (1.3 min vs 4.2 min; p < 0.01) - Time to defibrillation (2.6min vs 5.9min; p < 0.01)
Maes et al 2015 (238)  Brussels, Belgium, **	1) Survey of AED knowledge  2) Simulated OHCA scenario using manikin and AED directly linked to a call-centre: 2-way audio access activated on removing AED from location  Volunteers randomly selected from hospital visitors	<b>FACILITATOR</b> 65.9% (56/85) volunteers retrieved AED 47.1% (40/85) occasions AED contacted EMS (because volunteers had not tried to contact EMS or had used the wrong number) 62.4% (53/85) managed to use AED, following instructions given through device by EMS  <b>NEUTRAL</b> Younger volunteers (< 30 years, c.f. 31-60 years and >60 years) delivered a shock with AED in a shorter time
Agerskov et al 2015 (176)  Copenhagen, Denmark, 2011-2013	Observational study  Investigating AED deployment in OHCA occurring within 100m of a known AED  Data collected from online network linked to EMS/dispatch	<b>BARRIER</b> EMS Dispatch referred bystander to AED in 30.3% (20/66) cases when AED present within 100m <i>and</i> available for use (or 4.6% (20/436) total OHCA) Dispatched-referred AED applied in 10.6% (7/66) cases (14 other uses without dispatch assistance)
Zijlstra et al 2014 (168)  Netherlands, 2010-2013	Observational study  Registry review of OHCA in which AED were applied  Report on proportion of these OHCA that were attended by volunteers alerted by text-message system.  Volunteers alerted by EMS Dispatch if within 1000m of OHCA; also informed if an AED is within 500m of their location	<b>FACILITATOR</b> Volunteer activated by text-message system applied AED in: - 12.0% (184/1536) cases in total - 23.1% (184/797) cases when AED was applied before arrival of EMS
Deakin et al 2014 (220)  Hampshire, England, 2011-2012	Observational study  Registry review of EMS-attended OHCA Review of 999 call recordings	<b>BARRIER</b> AED reported available during 999 call in 4.3% (44/1035) OHCA AED applied in 40.9% (18/44) of these cases (1.7% of total OHCA) Occasions when AED available but not discussed in 999 call / no EMS Dispatch referral made was not reported
Nielsen et al 2013b (243)	Observational study	<b>BARRIER</b>

	Denmark, 2010-2011	Reviewing use of 807 AED (from one manufacturer) in Denmark	40 cases of OHCA where AED was used after implementation of a computer database allowing EMS Dispatch to refer patient to nearest AED A bystander was directed to nearby AED in 12.5% (5/40) cases.
	Rea et al 2011 (249) Washington state, USA, 2007-2009	Observational study Retrospective review of OHCA for which EMS were dispatched	<b>BARRIER</b> In 4.2% (32/763) OHCA, AED was applied before arrival of EMS; 2.9% (22/763) by lay public In other 731 OHCA, there were 18 cases with an AED present on-site and 40 more cases with an AED within 0.1 mile registered in the EMS Dispatch system In the 18 cases when registered, on-site AED that were not used: - EMS Dispatch notified caller of its presence in 3 OHCA - There were <b>no cases</b> where AED was used
	Harve et al 2007 (229) Finland, 2006	Simulation RCT Military conscripts with no previous medical training VF OHCA scenario; instructed to call 112 and follow dispatch instructions Intervention group: CPR and AED instructions (n = 14 teams of two) Control group: CPR instructions (n=13)	<b>FACILITATOR</b> 78.6% (11/14) teams in AED group managed to deliver shock; 64.2% (9/14) did so between 4-5 minutes <b>NEUTRAL</b> AED dispatch instructions did not make a significant difference to CPR quality (no difference between intervention and control groups)
	Ecker et al 2001 (221) Washington state, USA, **	Simulation RCT 75 adults aged 58-84 in each group, six months after AED training Simulated VF cardiac arrest Intervention group: received telephone assistance from 'dispatcher' Control group: No dispatcher assistance	<b>FACILITATOR</b> The intervention group were significantly more likely than the control group to correctly deliver a shock with the AED (91%, 68/75 vs 68%, 51/75; p = 0.001) <b>BARRIER</b> Among those who <i>did</i> deliver shock with AED, it took longer to do so in the intervention group than the control group (median 193s vs 148s; p = 0.001)
<b>AED Locator Systems</b>	Sakai et al 2011 (253) Osaka, Japan, 2009	Simulation RCT Participants required to locate AED Intervention group: had access to web-based AED locator software Control group did not	<b>NEUTRAL</b> No difference between intervention and control groups in time to bring AED to simulated victim (mean 400s vs 407s, p = 0.92), despite reduction in travel distance in intervention group (mean 606m vs 891m, p = 0.019) <i>Actual distance to AED was 120m and 170m at the two sites</i>
<b>Demographic Factors</b>	Griffis et al 2016 (225) Philadelphia, USA, **	Observational study Registry review of AED Studying characteristics of AED locations	<b>NEUTRAL</b> Proportion of % African American residents or employees had no effect on AED coverage <b>BARRIER</b>

	AED coverage defined as 400m radius around AED	Areas with high (>65%) AED coverage had (c.f. low (<35%) and medium (35-65%): <ul style="list-style-type: none"> <li>- Higher median household incomes (p = 0.006)</li> <li>- Higher proportion unemployed (p = 0.007).</li> <li>- Higher proportion earning more than \$40,00 (p = 0.008).</li> </ul>
Gonzalez et al 2015 ( <a href="#">265</a> )  Pennsylvania, USA, 2013	Face-to-face surveys  Administered at two train stations  Two surveys: one asking about AED unprompted; one showing a picture of an AED and asking about it. Other questions common to both surveys  514 respondents	<b>NEUTRAL</b> No differences in age or gender for: <ul style="list-style-type: none"> <li>- Knowledge about what an AED is used for (direct questioning)</li> <li>- Ability to correctly identify AED (when shown photograph)</li> </ul>
Bogle et al 2013 ( <a href="#">213</a> )  Illinois, USA, 2011	Online survey  University students  267/1000 (26.7%) response rate	<b>NEUTRAL</b> "No demographic variable was found to be associated with knowledge or attitudes towards AED or CPR." (verbatim)
Ong et al 2013 ( <a href="#">245</a> )  Singapore, 2009-2010	Face-to-face interviews (visiting lay public unannounced at home)  4192 respondents (62.5% response rate)	<b>NEUTRAL</b> Factors significantly affecting likelihood of having been trained in AED or holding a valid certificate (p<0.05 for both): <ul style="list-style-type: none"> <li>- Male</li> <li>- Age ≤ 35 years</li> <li>- Malay race (c.f. Chinese, Indian, other)</li> <li>- A-levels or Diploma (c.f. O-levels or higher degree)</li> <li>- Employed (c.f. unemployed or retired)</li> </ul>
Schober et al 2011 ( <a href="#">254</a> )  Amsterdam, Netherlands, **	Face-to-face surveys  Public location  1018 respondents from 38 nations	<b>FACILITATOR</b> North Americans, compared to Europeans and 'Other': <ul style="list-style-type: none"> <li>- More often recognise AED: 75% vs 45% vs 31%</li> <li>- More often know purpose of AED: 75% vs 53% vs 35%</li> <li>- More often willing to use AED 65% vs 46% vs 42%</li> </ul> Europeans, compared to North Americans and 'Other': <ul style="list-style-type: none"> <li>- More aware of PAD programmes 48% vs 18% vs 6%</li> </ul> <b>BARRIER</b> Comment that study not powered for subgroup analysis, but authors note: <ul style="list-style-type: none"> <li>- Women more often unwilling to use AED (40% female vs 53% male)</li> <li>- &lt;25yrs (38%) and &gt;60yrs (44%) less willing use AED than 25-39yrs (51%) and 40-59yrs (56%)</li> </ul>
Enami et al 2011 ( <a href="#">264</a> )	Written survey to participants of BLS courses and safe-driving courses	<b>NEUTRAL</b> Significant difference in ability to use AED according to age:

	Ishikawa prefecture, Japan, 2007-2009	Analysed 87.5% (22692/25922) surveys  Four scenarios, one including AED use	<ul style="list-style-type: none"> <li>- 28.8% (1730/6001) aged 17-29 years</li> <li>- 20.7% (168/812) aged 30-59 years</li> <li>- 8.4% (1172/13980) aged 60+ years</li> </ul> <p>Significant difference in willingness to use AED in OHCA situation according to age:</p> <ul style="list-style-type: none"> <li>- 56.8% (3386/5963) aged 17-29 years</li> <li>- 48.4% (388/801) aged 30-59 years</li> <li>- 21.3% (2832/13,285) aged 60+ years</li> </ul> <p>Other significant predictors of willingness to use AED were:</p> <ul style="list-style-type: none"> <li>- Being a student (60.5%) vs no steady job (48.7%) vs employed (43.0%) in the under 60s</li> <li>- Unemployed (23.3%) vs employed (20.7%) in the over 60s</li> <li>- Male gender (22.2% vs 17.5%) in the 60+ age group</li> </ul>
	Groh et al 2007 (226)  USA and Canada, 2000-2003	Observational study  Analysis of the North American PAD Trial	<p><b>NEUTRAL</b> Likelihood of having responded to an emergency</p> <ul style="list-style-type: none"> <li>- Age and sex had <b>no effect</b></li> </ul> <p><b>BARRIER</b> Likelihood of having responded to an emergency</p> <ul style="list-style-type: none"> <li>- Ethnic minority status (self-reported): <b>less likely</b></li> <li>- Formal education beyond high-school: <b>less likely</b></li> </ul>
	Lubin et al 2004 (237)  USA, 2001	Face-to-face survey  Public location  359 respondents	<p><b>NEUTRAL</b> No significant differences in age and gender to likelihood of future use of AED</p>
	Meischke et al 2002 (240)  Washington state, USA, **	Written survey  Immediately after re-training in AED use (initial training 3 months previously)  159 respondents  "Seniors" (mean age 71.3 years)	<p><b>NEUTRAL</b> Age and gender had <b>no effect</b> on future intention to use AED in OHCA scenario</p>
<b>Human Factors</b>	Zinckernagel et al 2017 (263)  Denmark, 2012-2013	Face-to-face semi-structured interviews with 9 school leaders and 1 teacher  Four focus groups with 3-5 teachers from same school in each  Concentrating on opinions of AED deployment and training	<p><b>FACILITATOR</b> Public-access AED believed to be important, especially where EMS response intervals are long AED perceived to be more effective than CPR</p>

	Qualitative (thematic) analysis	
Zijlstra et al 2015 (262) Netherlands, 2013-2014	Qualitative Interviews with lay rescuers who responded to a text-message alert system, and provided CPR and/or AED  82.5% (189/229) response rate	<b>FACILITATOR</b> 81% reported no stress after the event 19% mild stress only None reported moderate or severe stress  <b>BARRIER</b> 13% reported a severe <i>short-term</i> psychological impact Not attaching an AED, and not experiencing a positive outcome correlated with the likelihood of mild stress
Ong et al 2013 (245) Singapore, 2009-2010	Face-to-face interviews (visiting lay public unannounced at home)  4192 respondents (62.5% response rate)	<b>BARRIER</b> People's beliefs about AED training and practice differ - 57.2% (2397/4192) believe adults should be trained in AED, but only 10.7% (449/4192) had been trained, and only 3.7% (155/4192) held a valid certificate  Fewer thought adults should be trained in AED (57.2%, 2397/4192) compared to CPR (82.6%, 3464/4192).
Timmons et al 2008 (259) England, 2003-2004	53 Qualitative Interviews; 9 with AED trainers, 44 with laypeople trained in AED use  From organisations that had AED provided under the 'Defibrillators in Public Places' scheme	<b>FACILITATOR</b> Respondents trust the AED to a high degree to do what it is designed to AED reduces levels of panic, fear of litigation in resuscitation efforts in general Respondent trust the organisation and training structure within which the AED operates
Davies et al 2008 (219) Barry, Wales, 2005	6 Qualitative Interviews  First responders involved in at least 25 emergency responses as part of a PAD scheme	<b>FACILITATOR</b> Inbuilt resilience noted when responding with an AED, aided by a clear sense of role and responsibility
Peberdy et al 2006 (246) USA and Canada, 2000-2003	Observational study  Review of adverse events from the North American PAD Trial	<b>FACILITATOR</b> 20,396 lay volunteers trained, and there were just 7 adverse events reported: - 1 muscle pull - 4 with increased emotional stress requiring intervention - 2 who felt pressurised to volunteer by their employer

## 14.2 INTERVIEW STUDY (CHAPTER 8)

### 14.2.1 Participant Information Sheets

#### *GoodSAM responder interviews*



**Dear GoodSAM responder,**

**Date: xx.xx.2018**

You are being invited to take part in a telephone interview study because you have received a GoodSAM notification about a nearby cardiac arrest in the London area in the past seven days.

Before you decide whether or not to take part, you need to understand why the study is being done and what it would involve for you. Please take the time to read the following information carefully. Talk to others about the study if you wish.

Part 1 tells you the purpose of the study and what will happen to you if you take part. Part 2 gives you more detailed information about the conduct of the study. Please feel free to reply to this e-mail if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

#### **PARTICIPANT INFORMATION SHEET**

**Study Title:** Investigating Automated External Defibrillator use by GoodSAM first-responders

**Investigators:** Dr. Christopher Smith, Professor Gavin Perkins, Professor Frances Griffiths, Dr. Ranjit Lall

#### **PART 1**

**What is the study about?**

We are investigating how often GoodSAM responders are responding to notifications, how often they are using Automated External Defibrillators (sometimes also called 'AEDs' or 'Public-Access Defibrillators'), and the reasons behind this. We hope to understand how we could make it easier for GoodSAM responders to use an Automated External Defibrillator in the future. **We would like to hear from people regardless of whether or not they were able to respond to the GoodSAM notification.**

The purpose of the study is to explore your choices related to responding to incidents. We are not looking to pass judgement on decisions you have made or your ability to respond in situations. Instead, we are interested in hearing about how the process works for you and we are interested in the accessibility of Automated External Defibrillators.

We would like to conduct a brief interview – around 15 minutes long – over the telephone. The interview will be recorded. This interview can take place at any time to suit you, including at evenings or weekends.

### **Do I have to take part?**

It is entirely up to you to decide. The study is fully described in this Participant Information Sheet. Please also read the consent statements at the end to see whether or not you agree with them. If you do not wish to take part you do not have to reply to us or take any further action. We will not contact you again.

### **What happens now if I wish to take part?**

- Reply to this e-mail with a suitable telephone number on which we can contact you
- Dr. Smith (the primary investigator in the study) will contact you either by text or e-mail to arrange a time for the interview. You can take part in this interview in any setting that you please, at a time to suit you.
- Dr. Smith will ring at the agreed time, check that you are still happy to take part, and conduct the interview

Before the interview starts, there will be a chance to ask any further questions about the study. The consent statements will be read out again to make sure that you still agree and still wish to take part. The interview will be recorded and a written transcript produced. All information that you provide will be anonymised. Interview recordings and transcripts will be stored separately, identifiable only by a unique number. Your name, contact details and any other identifiable information will NOT be stored.

You are free to end the interview and/or withdraw from the study without giving a reason. This will not affect you or your circumstances in any way.

You can also choose to withdraw from the study after the interview has taken place and, wherever possible, your data will not be used. However, please note that once your data has been anonymised and analysed, and the study has been published, it will not be possible to identify the information that specifically came from you. It would therefore not be possible at this point to remove your data from published material (although it will not be possible to attribute information to a specific individual).

**What are the possible disadvantages, side effects, risks, and/or discomforts of taking part in this study?**

You will be asked to recall what may have been a distressing event for you. It is possible that you will find it difficult to talk on the telephone about this.

You may take a break from the interview or end the interview at any time should you feel distressed or upset, or for any other reason. You can decide to continue the interview soon afterwards, re-schedule the interview for another time or not continue with the interview at all. You can decide whether we can use the information recorded up until that point or to withdraw from the study – in which case your information would not be used.

If you feel you need emotional or psychological support, you may find the following sources helpful:

- Your own GP
- NHS 111
- Samaritans: 116 123 (from any phone)
- Mind: 0300 123 3393 (phone); 86463 (text)
- Bystander Support Network: <http://www.bystandernetwork.org/> – an online community-engagement network set up to help people who have been involved in a community cardiac arrest case.

**If you are an employee of London Ambulance Service**, you can contact the Senior LINC on-call (at any time, 24/7) on 0207 9227539.

In addition, should the interviewer have IMMEDIATE concern about the participant's wellbeing, they will call 999 for emergency assistance from the ambulance service. In this case the interviewer would ask for your current location in order to help the ambulance service locate you in a timely manner. The interviewer will try and remain on the telephone with you until help arrives.

**What are the possible benefits of taking part in this study?**

There are no direct benefits to you. The results of the study will inform the development of systems for community defibrillation. If you receive a GoodSAM notification in the future what we discover may make it easier for you to use an Automated External Defibrillator.

## **Expenses and payments**

There will be no payments nor expenses for taking part in the study.

## **What will happen when the study ends?**

All data collected in this study and any other materials associated with this study will be kept on secure file-servers at the University of Warwick for at least 10 years after any publication based upon this study. These files are encrypted and password-protected. Only the investigators listed above will have access to this data. This is in line with the Research Data Management Policy and Confidentiality Policy at the University of Warwick.

## **Will my taking part be kept confidential?**

Yes. We will follow strict ethical and legal practice and all information about you will be handled in confidence. Further details are included in Part 2.

## **What if there is a problem?**

We will address any complaint about the way you have been dealt with during the study or any possible harm that you might suffer. Detailed information is given in Part 2.

**This concludes Part 1. If the information in Part 1 has interested you and you are considering taking part, please read the additional information in Part 2 before making any decisions.**

## **PART 2**

### **Who is organising and funding the study?**

This work is being funded by a Doctoral Research Fellowship awarded to Dr. Smith by the National Institute for Health Research. The study is being conducted as part of his PhD in Health Sciences at the University of Warwick.

### **What will happen if I do not want to carry on being part of the study?**

Participation in this study is entirely voluntary. Refusal to take part will not affect you in any way. If you decide to take part in the study, you will need to verbally give your consent to take part, which will be recorded as part of the interview process.

Participation in this study is entirely voluntary. Refusal to take part will not affect you or your employment in any way. If you decide to take part in the study, you will need sign a consent form prior to the beginning of the interview.

A copy of the consent form is attached to this e-mail so that you can familiarise yourself with the statements.

You are free to end the interview and/or withdraw from the study without giving a reason. This will not affect you or your circumstances in any way.

You can also choose to withdraw from the study after the interview has taken place and, wherever possible, your data will not be used. However, please note that once your data has been anonymised and analysed, and the study has been published, it will not be possible to identify the information that specifically came from you. It would therefore not be possible at this point to remove your data from published material (although it will not be possible to attribute information to a specific individual).

You have the right to decline any further contact by study staff after you withdraw.

### **What if there is a problem?**

This study is covered by the University of Warwick's insurance and indemnity cover. If you have an issue, please contact the Principal Investigator of the study, Dr Christopher Smith at [c.smith.20@warwick.ac.uk](mailto:c.smith.20@warwick.ac.uk)

### **Who should I contact if I wish to make a complaint?**

Any complaint about the way you have been dealt with during the study or any possible harm you might have suffered will be addressed. Please address your complaint to the person below, who is a senior University of Warwick official entirely independent of this study:

#### **Deputy Director / Head of Research Governance**

Research & Impact Services

University House

University of Warwick

Coventry

CV4 8UW

Tel: 024 76 522746

Email: [researchgovernance@warwick.ac.uk](mailto:researchgovernance@warwick.ac.uk)

### **Will my taking part be kept confidential?**

All data collected in this study and any other materials associated with this study will be kept on secure file-servers at the University of Warwick for at least 10 years after any publication based upon this study. These files are encrypted and password-protected. Only the investigators listed above will

have access to this data. This is in line with the Research Data Management Policy and Confidentiality Policy at the University of Warwick.

The fact that you have been invited to take part in this study and whether or not you decided to participate will not be shared with any other party.

### **What will happen to the results of the study?**

We anticipate that the results of this study will be published in an international scientific journal and presented at national and international healthcare conferences. The key findings of the research will be shared with GoodSAM, London Ambulance Service, public and patient involvement groups and the National Institute for Health Research.

The results will be an amalgamation of the findings from at least 30 different interviews and from anonymised data already collected about cardiac arrest patients in London. We will make sure that it is not possible to identify any individual or event from any information that is published or reported in public.

### **Who has reviewed the study?**

This study has been reviewed and given favourable opinion by the University of Warwick's Biomedical and Scientific Research Ethics Committee (BSREC).

BSREC number: REGO-2018-2164

Date of Approval: 16.03.18

### **What if I want more information about the study?**

If you have any questions about any aspect of the study, or your participation in it, not answered by this participant information leaflet, please contact:

Dr. Christopher Smith

[c.smith.20@warwick.ac.uk](mailto:c.smith.20@warwick.ac.uk)

Professor Gavin Perkins

[g.d.perkins@warwick.ac.uk](mailto:g.d.perkins@warwick.ac.uk)

**Thank you for taking the time to read this Participant Information Sheet**

## **Key Informant Interviews**



**Date:**

**Dear**

You are being invited to take part in a face-to-face interview because you have been involved in the interaction between GoodSAM and London Ambulance Service dispatch systems.

Before you decide whether or not to take part, you need to understand why the study is being done and what it would involve for you. Please take the time to read the following information carefully. Talk to others about the study if you wish.

Part 1 tells you the purpose of the study and what will happen to you if you take part. Part 2 gives you more detailed information about the conduct of the study. Please feel free to reply to this e-mail if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

### **PARTICIPANT INFORMATION SHEET**

**Study Title:**           **Investigating Automated External Defibrillator use by GoodSAM first-responders**

**Investigators:**       **Dr. Christopher Smith, Professor Gavin Perkins, Professor Frances Griffiths, Dr. Ranjit Lall**

#### **PART 1**

##### **What is the study about?**

We are investigating how often GoodSAM responders are responding to notifications, how often they are using Automated External Defibrillators (sometimes also called 'AEDs' or 'Public-Access Defibrillators'), and the reasons behind this. We hope to understand how we could make it easier for GoodSAM responders to use an Automated External Defibrillator in the future.

We would like to conduct a brief face-to-face interview – no more than 30 minutes long. The interview will be recorded. This interview can take place be at any time to suit you, but would ideally be at your place of work.

At the end of the interview, if you wish, you may demonstrate the GoodSAM system (and how it integrates with London Ambulance Service dispatch systems) to your interviewer. This part of the interaction will not be recorded, but the interviewer may take notes

### **Do I have to take part?**

It is entirely up to you to decide. The study is fully described in this Participant Information Sheet. Please also read the consent statements at the end to see whether or not you agree with them. If you do not wish to take part you do not have to reply to us or take any further action. We may send one follow-up e-mail if we do not hear from you, but after that we will not contact you again.

### **What happens now if I wish to take part?**

- Reply to this e-mail indicating your willingness to take part
- Dr. Smith (the primary investigator in the study) will contact you either by phone or e-mail to arrange a suitable time and location for the interview

Before the interview starts, there will be a chance to ask any further questions about the study. The consent statements will be read out again to make sure that you still agree and still wish to take part. The interview will be recorded and a written transcript produced. All information that you provide will be anonymised. Interview recordings and transcripts will be stored separately, identifiable only by a unique number. Your name, contact details and any other identifiable information will NOT be stored.

You are free to end the interview and/or withdraw from the study without giving a reason. This will not affect you or your circumstances in any way.

You can also choose to withdraw from the study after the interview has taken place and, wherever possible, your data will not be used. However, please note that once your data has been anonymised and analysed, and the study has been published, it will not be possible to identify the information that specifically came from you. It would therefore not be possible at this point to remove your data from published material (although it will not be possible to attribute information to a specific individual).

### **What are the possible disadvantages, side effects, risks, and/or discomforts of taking part in this study?**

This will involve 30-60 minutes of your time, and this may well be during your normal working day.

You may take a break from the interview or end the interview at any time should you feel distressed or upset, or for any other reason. You can decide to continue the interview soon afterwards, re-schedule the interview for another time or not continue with the interview at all. You can decide whether we can use the information recorded up until that point or to withdraw from the study – in which case your information would not be used.

If you feel you need emotional or psychological support, you may find the following sources helpful:

- Your own GP
- NHS 111
- Samaritans: 116 123 (from any phone)
- Mind: 0300 123 3393 (phone); 86463 (text)
- Bystander Support Network: <http://www.bystandernetwork.org/> – an online community-engagement network set up to help people who have been involved in a community cardiac arrest case.
- **Employees of London Ambulance Service** can contact the Senior LINC on-call (at any time, 24/7) on 0207 9227539.

In addition, should the interviewer have IMMEDIATE concern about the participant's wellbeing, they will call 999 for emergency assistance from the ambulance service. In this case the interviewer would ask for your current location in order to help the ambulance service locate you in a timely manner. The interviewer will try and remain on the telephone with you until help arrives.

### **What are the possible benefits of taking part in this study?**

There are no direct benefits to you. However, you may contribute to ways of making it easier for GoodSAM responders to use an Automated External Defibrillator in the future. If you yourself are a GoodSAM responder and receive a notification what we discover may make it easier for you to use an Automated External Defibrillator.

### **Expenses and payments**

There will be no payments nor expenses for taking part in the study.

### **What will happen when the study ends?**

All data collected in this study and any other materials associated with this study will be kept on secure file-servers at the University of Warwick for at least 10 years after any publication based upon this study. These files are encrypted and password-protected. Only the investigators listed above will

have access to this data. This is in line with the Research Data Management Policy and Confidentiality Policy at the University of Warwick.

### **Will my taking part be kept confidential?**

Yes. We will follow strict ethical and legal practice and all information about you will be handled in confidence. Further details are included in Part 2.

### **What if there is a problem?**

We will address any complaint about the way you have been dealt with during the study or any possible harm that you might suffer. Detailed information is given in Part 2.

### **This concludes Part 1.**

**If the information in Part 1 has interested you and you are considering taking part, please read the additional information in Part 2 before making any decisions.**

## **PART 2**

### **Who is organising and funding the study?**

This work is being funded by a Doctoral Research Fellowship awarded to Dr. Smith by the National Institute for Health Research. The study is being conducted as part of his PhD in Health Sciences at the University of Warwick.

### **What will happen if I do not want to carry on being part of the study?**

Participation in this study is entirely voluntary. Refusal to take part will not affect you or your employment in any way. If you decide to take part in the study, you will need sign a consent form prior to the beginning of the interview. A copy of the consent form is attached to this e-mail so that you can familiarise yourself with the statements.

You are free to end the interview and/or withdraw from the study without giving a reason. This will not affect you or your circumstances in any way.

You can also choose to withdraw from the study after the interview has taken place and, wherever possible, your data will not be used. However, please note that once your data has been anonymised and analysed, and the study has been published, it will not be possible to identify the information that specifically came from you. It would therefore not be possible at this point to remove your data from published material (although it will not be possible to attribute information to a specific individual).

You have the right to decline any further contact by study staff after you withdraw.

### **What if there is a problem?**

This study is covered by the University of Warwick's insurance and indemnity cover. If you have an issue, please contact the Principal Investigator of the study, Dr Christopher Smith at [c.smith.20@warwick.ac.uk](mailto:c.smith.20@warwick.ac.uk)

### **Who should I contact if I wish to make a complaint?**

Any complaint about the way you have been dealt with during the study or any possible harm you might have suffered will be addressed. Please address your complaint to the person below, who is a senior University of Warwick official entirely independent of this study:

#### **Deputy Director / Head of Research Governance**

Research & Impact Services  
University House

University of Warwick  
Coventry  
CV4 8UW

Tel: 024 76 522746

Email: [researchgovernance@warwick.ac.uk](mailto:researchgovernance@warwick.ac.uk)

### **Will my taking part be kept confidential?**

All data collected in this study and any other materials associated with this study will be kept on secure file-servers at the University of Warwick for at least 10 years after any publication based upon this study. These files are encrypted and password-protected. Only the investigators listed above will have access to this data. This is in line with the Research Data Management Policy and Confidentiality Policy at the University of Warwick.

The fact that you have been invited to take part in this study and whether or not you decided to participate will not be shared with any other party.

### **What will happen to the results of the study?**

We anticipate that the results of this study will be published in an international scientific journal and presented at national and international healthcare conferences. The key findings of the research will be shared with GoodSAM,

London Ambulance Service, public and patient involvement groups and the National Institute for Health Research.

The results will be an amalgamation of the findings from at least 30 different interviews and from anonymised data already collected about cardiac arrest patients in London. We will make sure that it is not possible to identify any individual or event from any information that is published or reported in public.

**Who has reviewed the study?**

This study has been reviewed and given favourable opinion by the University of Warwick's Biomedical and Scientific Research Ethics Committee (BSREC).

BSREC number: REGO-2018-2164

Date of Approval: 16.03.18

**What if I want more information about the study?**

If you have any questions about any aspect of the study, or your participation in it, not answered by this participant information leaflet, please contact:

Dr. Christopher Smith

[c.smith.20@warwick.ac.uk](mailto:c.smith.20@warwick.ac.uk)

Professor Gavin Perkins

[g.d.perkins@warwick.ac.uk](mailto:g.d.perkins@warwick.ac.uk)

**Thank you for taking the time to read this Participant Information Sheet**

## 14.2.2 Consent forms

### ***GoodSAM responder interviews***

Sent as e-mail attachment and then read out at start of telephone interview.



**Study Number:** REGO-2018-2164

**Title of Project:** Investigating Automated External Defibrillator use by GoodSAM first-responders

**Name of Researcher:** Dr. Christopher Smith

Please consider these consent statements and whether or not you agree with them. If you agree to be contacted for a telephone interview these statements will be read aloud to you at the start of the interview process. You will be asked to answer “yes” or “no” for each statement.

1. I confirm that I have read and understand the Participant Information Sheet e-mailed to me for this study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my circumstances being affected.
3. I understand that this telephone interview will be recorded and that a transcript of the conversation will be made. The interview may be listened to and the transcript may be read by the project’s research team. I give permission for members of the project’s research team to have access to this recording and transcript.
4. I agree to take part in the study.

**Key Informant interviews**



**CONSENT FORM**

**Study Number:** REGO-2018-2164

**Title of Project:** Investigating Automated External Defibrillator use by GoodSAM first-responders

**Name of Researcher:** Dr. Christopher Smith

1. I confirm that I have read and understand the Participant Information Sheet e-mailed to me on \_\_\_ / \_\_\_ / \_\_\_ for this study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my circumstances being affected.
3. I understand that the face-to-face interview will be recorded and that a transcript of the conversation will be made. The interview may be listened to and the transcript may be read by the project's research team. I give permission for the project's research team to have access to this recording and transcript.
4. I understand that, if I demonstrate how the GoodSAM and London Ambulance Service systems work, direct observations will be made and notes may be taken. These notes may be reviewed by any of the researchers named above. I give permission for these individuals to have access to this recording and transcript.
5. I agree to take part in the study.

\_\_\_\_\_  
Name of Participant

\_\_\_\_\_  
Date

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Name of Person taking consent

\_\_\_\_\_  
Date

\_\_\_\_\_  
Signature

### 14.2.3 Interview schedules and topic guides

*GoodSAM responder interviews*

#### Interview Schedule

Words in quotation marks will be spoken aloud to the participant. The rest is for the interviewer's information only.

#### **1. Pre-ample**

"Good (morning/afternoon/evening)."

"This is Chris Smith from the University of Warwick. [pause, normally they acknowledge]. Hopefully you're expecting my call because you recently received a GoodSAM notification." *Participant confirms this*

"Just to make sure I am talking to the right person, could I just confirm your full name please?" *This identifies the participant by name. We have not identified them as a GoodSAM volunteer at this point – it is conceivable that they might wish to keep this information private.*

"Could I confirm what previous level of healthcare experience you have – this will form part of our later analyses".

*This identifies the interviewee by category of responder – which is the other piece of information that we already know – and is important to confirm as we are stratifying by GoodSAM responder category.*

"Thank you for agreeing to participate in this interview, which forms part of a research study being completed in conjunction with GoodSAM and London Ambulance Service. It is also part of a PhD that I am studying for at the University of Warwick. I am also an A&E doctor, but I should just clarify that I am interviewing you in my role as a PhD student at the University, and not because I am a doctor."

"Did you receive the participant information sheet and the consent statements? Have you had opportunity to read them? Do you have any questions about the interview process before we begin?"

"The purpose of this research is not in any way to make judgements on decisions that you have made, but to understand what might make such decisions easier in the future."

“Could I ask if anything has changed since you signed the consent form and are you still happy to proceed with the interview?”

“I need to run through the four consent statements that were in the e-mail. I’ll start the recording now so that there is a record of these statements – OK, we’re recording.

“It’s [date] and [time]. Can you indicate if you agree with each statement with ‘yes’ or ‘no’.”

[READS OUT CONSENT STATEMENTS]

“OK, the recording will continue until the telephone call ends. You are free to pause or stop the interview at any time. OK, let’s begin.

## **2. Questions – see separate Interview Topic Guide**

- Non-judgmental
- Remember that it is an interview and not ‘just a chat’
- Don’t be afraid of the silences
- Using the probing questions only if the answers are not forthcoming
- If pertinent questions occur, note down and follow-up
- It is OK to take notes, which may include personal reflections on how the interview is going
- *Remember that this may be a sensitive subject and most respondents (even those clinically trained) will not have had as much exposure to cardiac arrest / unexpected death and its aftermath as you.*

## **3. Wrap-up**

“Well, I don’t have any further questions, so that is the end of the interview.”

“Thank you very much for taking part, and have a good (day/evening).”

[If the tone/nature of the conversation substantially changes at this point, remind the participant that we are still recording until the phone call ends]

## **4. Advice and other important information**

### Clinical Questions

Do not offer clinical advice and do not suggest a course of action for next time out. If pressed, be clear that it is not your role to do this. They can access the following sources of information for advice:

- GoodSAM – can provide technical information about GoodSAM, guidance on liability, and has detailed information about data protection and other governance issues
- Resuscitation Council (UK) – online resource. It provides guidelines about Cardiopulmonary Resuscitation and the use of an Automated External Defibrillator.

Medical professionals who have questions or concerns about liability should be directed to the GoodSAM webpages or advised to consult their defence organisation or union.

### Concerns for Welfare of Interview Participant

If there are concerns about the participant and you provide assistance (see below), you are acting in a Good Samaritan capacity.

If there are **immediate** concerns about the safety of the patient (see Warwick CTU Action Card):

- Confirm address if possible
- Call 999 – it is likely you will go to WMAS switchboard, you may need to specify that the call relates to someone out-of-area

If you do not have concerns about safety but think they may require support, the following are professional sources of information (numbers last checked on 23/11/17):

- Their own GP
- NHS 111
- Samaritans: 116 123 (from any phone)
- Mind: 0300 123 3393 (phone); 86463 (text)
- Bystander Support Network: <http://www.bystandernetwork.org/> – an online community-engagement network set up to help people who have been involved in a community cardiac arrest case.
- In addition, for those who are **employees of London Ambulance Service**, they can contact the Senior LINC on-call (24/7) on 0207 9227539.

Note that this information listed in section 4 will also be detailed in the Participant Information Sheet.

### Brief Interview Topic Guide

#### **Opening question**

- “Can you tell me as much as you can about what happened when you received the GoodSAM notification from [last Thursday]?” [Clarify whether they responded to the notification or not]

[Give the participant ample time to tell the story. Probing questions only required if information is not forthcoming]

1. If they responded to the notification:

- Probing:
  - “Can you tell me what affected your decision to respond?” [motivation: planned responses / instinct]
  - “Was there anything about the situation that affected your decision to respond [opportunity: time, place, responsibilities, environment]
  - “When you responded, did you feel confident that you could provide effective assistance to the *person you were notified about*\* if needed? [capability: knowledge / skills / experience]

[\* If the respondent uses a specific term (e.g. “the woman” or “the victim” then it is appropriate to use this term instead]

- “Did you get to the person you were notified about?” [clarify whether this was before the ambulance arrived or not]
  - Yes: “Did you experience any issues getting to him/her”
  - No: “What prevented you from getting to the him/her”
- “Did you take a defibrillator to scene?” [may need to clarify term e.g. “Public-access defibrillator”, “AED”]

*If yes to defibrillator, probing:*

- Can you tell me what affected your decision to fetch a defibrillator? [motivation]
- “Did you experience any issues getting the defibrillator?” [opportunity]
- “When you decided to fetch a defibrillator, did you feel confident that you could use it effectively?” [capability]
- “Did you feel confident when you were actually using the defibrillator?” [capability]

*If no to defibrillator*

- “What affected your decision not to fetch a defibrillator?”
- “Would you consider fetching a defibrillator in the future if one was nearby?” “Why?”
- *Probing:*
  - “What would affect this decision?” [motivation]
  - “Do you feel you would be able to get to a defibrillator and take it to the person you were notified about?” [opportunity]
  - “Do you feel confident that you could use the defibrillator effectively if required?” [capability]

2. If they did not respond to the notification:

- Can you tell me what would help you respond in the future?
- *Probing:*
  - “What would affect this decision?” [motivation]
  - “Was there anything about the situation that made it difficult for you to respond?” [opportunity]
  - “If you had responded, do you feel confident that you could have provided effective assistance to the person you were notified about if required?” [capability]
- “Would you consider fetching a defibrillator first in the future?” “Why?”
- *Probing:*
  - “What would affect this decision?” [motivation]
  - “Do you feel you would be able to get to a defibrillator and take it to the person you were notified about?” [opportunity]
  - “Do you feel confident that you could use the defibrillator effectively if required?” [capability]

## **Wrapping up**

- How long have you been a GoodSAM volunteer for?
- Have you attended an OHCA before?
- “Is there something important that I have not asked you about, or that you wish to share now?”

## *Key Informant interviews*

### Key Informant – Interview Schedule

#### **1. Introductions**

This will be a face-to-face meeting, and is likely to be at the participant’s place of work. If this is the case, introductions will be made and the identity of the participant clarified before the formal interview process starts. The participant will have had chance to read consent statements before the face-to-face meeting, but they will be asked to sign a consent form in person before the start of the interview.

“Thank you for agreeing to participate in this interview, which forms part of a research study being completed in conjunction with GoodSAM and London Ambulance Service. It is also part of a PhD that I am studying for at the University of Warwick. I am also an A&E doctor, but I should just clarify that I am interviewing you in my role as a PhD student at the University, and not because I am a doctor.”

“Did you receive the participant information sheet and the consent statements? Have you had opportunity to read them? Do you have any questions about the interview process before we begin?”

“Could you read and sign this consent form please if you are still happy to proceed with the interview?”

“I’ll start the recording now – OK, we’re recording. It’s [date] and [time]. The recording will continue until the end of the interview”

## **2. Questions – Brief Topic Guide**

- “Can you tell me about the GoodSAM system and how it interacts with London Ambulance Service systems?”
- “In what ways have the GoodSAM system and how it interacts with London Ambulance Service systems worked well?”
- “Are there any problems that you have encountered with GoodSAM system and how it interacts with London Ambulance Service systems?”
- “Do you have any suggestions about how the system could be improved to increase the number of notifications that are accepted by GoodSAM responders?”
- “Do you have any suggestions about how the system could be improved to increase Automated External Defibrillator use by GoodSAM responders?”
- “Is there something important that I have not asked you about, or that you wish to share now?”

## **3. Wrap-up**

“Well, I don’t have any further questions, so that is the end of the interview.”

“Thank you very much for taking part, and have a good (day/evening).”

## **4. Observation**

After interviewing the Key Informant, it may be pertinent for them to demonstrate GoodSAM or London Ambulance Service systems. It will not be practical to record this portion of the visit (as it may be in a busy / shared work environment) but field notes will be taken.

**14.2.4 Warwick Clinical Trials Unit ‘Sensitive Interview Action’ card**

