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Research

Public access defibrillation: utilisation and missed opportunities

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Abstract

Introduction

Automated external defibrillators (AEDs) for public use are becoming increasingly prevalent, but little is known about utilisation. The purpose of this study was to compare the locations of out-of-hospital cardiac arrests (OHCAs) to the locations of AEDs to determine whether missed opportunities exist.

Methods

A retrospective study was performed of all OHCAs in which resuscitation was attempted between 1 January 2005 and 31 December 2010 in Orange County, North Carolina, United States of America, a mixed suburban/rural emergency medical services (EMS) system. Emergency medical services records were used to determine public AED utilisation and OHCA location. The locations were plotted on a map using ArcGIS. Businesses, public buildings and facilities located within a 100 metre radius of each OHCA were surveyed to determine AED availability. Data were analysed using standard descriptive statistics.

Results

During the study period, 307 OHCAs occurred at 282 locations. Of these, 219 (71%) occurred in private homes, 26 (9%) in nursing or assisted living facilities, and 62 (20%) in public locations. An AED location was within 100 metres of an OHCA location in 22 cases. Five cases were excluded due to the arrest being witnessed by EMS, and late or unknown AED installation time. Of the remaining 17 OHCAs, seven (41%) had a nearby AED that was not used, constituting a missed opportunity for deployment.

Conclusion

In nearly half of OHCAs that have a nearby public AED, the AED was not utilised. This suggests that public awareness and accessibility of AED locations should be improved.

Keywords:

AED; public access defibrillation programs; emergency medical services

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Introduction

Each year in the United States (US), an estimated 326,200 people experience cardiac arrest unexpectedly (outside a hospital) with an 88% mortality rate (1,2). When a person enters cardiac arrest, bystanders can start cardiopulmonary resuscitation (CPR) and apply an automated external defibrillator (AED) to that person. The American Heart Association's out-of-hospital cardiac arrest (OHCA) 'chain of survival' emphasises early CPR and early defibrillation (3-8). The chance of survival decreases by 10% per minute without CPR and defibrillation (9-11). However, high quality CPR and the use of an AED can mitigate this decrease to 4% per minute (12,13). In the few cities around the world that combine an active citizen CPR training program with coordinated access to AEDs, witnessed OHCA survival rates reach as high as 50% (3,4).

In recent years, public AEDs have increased in prevalence for timely use by the public (14-17). These public access defibrillation (PAD) programs have a potential to increase survival for patients suffering from OHCA, saving nearly 500 lives annually in the US and Canada, in a safe and cost-effective manner (8,18-24). However, the life-saving capability of these devices is limited if the public does not know what AEDs are, where they are located, or if the AEDs are inaccessible (25). If EMS centres had knowledge of AED locations, then bystanders could be directed to the nearest AED for use during an OHCA (26,27). Conversely, knowledge of historical OHCA locations can guide the placement of AEDs in the community based on 'high risk' locations (16,28-31). While the majority of OHCA occur in private residences, locations with high population density (eg. apartment complexes, nursing homes) and locations with high traffic (eg. shopping malls, sports facilities, public transportation stations) may be public sites of primary importance for AED placement (16,32,33). In areas with longer EMS response times, PAD programs may provide the first available attempt at defibrillation (12). Simply cataloguing and mapping the locations of AEDs with EMS call centres and relaying this information to bystanders may result in more rapid and frequent deployment of AEDs (26,27,34).

The primary aim of this study was to determine whether there are missed opportunities of PAD deployment, which we defined as an OHCA in which an AED was within 100 metres but not utilised. Knowing whether public AEDs are underutilised will emphasise future targeted efforts to improve PAD programs and integrate those programs into the EMS infrastructure in the US.

Methods

Study design

This retrospective observational cohort study of OHCA and associated survey of AED locations was performed via review of patient data abstracted from existing EMS patient care

reports (PCRs), hospital medical records and via phone survey of local businesses. In addition, the University of North Carolina Department of Environment, Health and Safety's AED database of the university's campus was used. The study protocol was reviewed and approved by the University of North Carolina Institutional Review Board.

Study setting and population

Orange County is a suburban/rural county located in central North Carolina, with an area of 397 square miles and a 2010 US Census population of 133,801. The county encompasses the towns of Chapel Hill, Carrboro, Hillsborough and parts of Mebane and Durham. Approximately 37.7% of people live outside city limits throughout the county. The Orange County Emergency Medical Services (OCEMS) system is comprised one county-based EMS ambulance service supplemented by four municipal and eight volunteer fire departments, and a technical rescue team. The OCEMS is an advanced life support system, sending at least one ambulance staffed by at least one paramedic to every EMS call for service. Fire departments are trained at the emergency medical responder level, with the exception being Carrboro Fire Department at the emergency medical technical level. In the 2009–2010 fiscal year (1 July to 30 June), OCEMS received 11,239 calls for service and transported 7944 patients to area hospitals. The agency also serves as the dispatch centre, where emergency telecommunicators utilise medical priority dispatch systems for their dispatch protocols. There are at least 100 OHCA per year of which half have resuscitation initiated by OCEMS. The rest meet criteria for not initiating resuscitation such as rigor mortis or obvious death (unpublished data, Brice, 2010).

Finding missed opportunities

We followed a two-step process to determine missed opportunities of PAD use in OHCA. In the first step all PCRs from 2005–2010 from OCEMS were reviewed. Inclusion criteria were any PCR categorised as an OHCA by responding EMS providers and in which resuscitation was attempted by the agency. The addresses of all OHCA were tabulated and mapped with ArcGIS 9.3 software (35). For PCRs that did not have a specific incident address, Google Maps was used to identify the nearest available address. For example, an OHCA that occurred in the middle of a park would use the park's numerical address. Geographic data were provided by the Orange County Division of GIS in order to develop a map with the superimposed OHCA across Orange County in the time period.

The second step involved mapping nearby AEDs. Using ArcGIS, a 100-metre buffer zone around each OHCA address was mapped (Figures 1 and 2). This distance was chosen based on previous research and American Heart Association guidelines (32,36-41). In these buffer zones, all businesses, as maintained by the Orange County and Chapel Hill-Carrboro Chambers of Commerce, were phone surveyed to determine

Figure 1. ArcGIS map of OHCA and AED in Chapel Hill and Carrboro. OHCA's have 100-metre buffer zone to determine AED overlap

Figure 2. ArcGIS map of OHCA and AED in Hillsborough. OHCA's have 100-metre buffer zone to determine AED overlap

AED accessibility. All variables were collected into a Microsoft Excel (2010, version 14.0, Redmond, WA) database. Data were analysed using standard descriptive statistics using Microsoft Excel. The two databases were compared to determine if there were AEDs nearby to OHCA but not utilised. The dates of the OHCA were compared to the date of AED installation (if available) at businesses to ensure temporal overlap. All PCRers involved in the overlap were reviewed to confirm PAD utilisation. Missed opportunities were defined as cases in which first responders applied an AED before EMS arrival when there was an AED unused by bystanders.

Results

During the study period there were 307 OHCA in 282 locations. Of these, 219 (71%) occurred in private homes; 62 (20%) occurred in public locations. The remaining 26 (9%) occurred in nursing or assisted living facilities. At the time of the phone survey, an AED location was within 100 metres of an OHCA location in 22 arrests. Four of these locations either had AED installation after the arrest occurred or an unknown installation date and were therefore excluded. One arrest was witnessed by EMS and was excluded.

Of the remaining 17 arrests, 59% (10) had an AED applied by bystanders to the patient before EMS arrival. These successful community deployments of an AED were at healthcare facilities (7), public pools (2) and at a senior community centre (1). There were seven confirmed (41%) public OHCA in which an AED was nearby but was not utilised, constituting a missed opportunity for PAD deployment (Figure 3). In two out of seven missed opportunities, an AED was at the same location as the OHCA. Five out of the seven arrests were witnessed by family or bystanders. In the two unwitnessed arrests, the AED was not on location but within walking distance behind locked doors after business hours in a school and primary care doctor's office. Both of these arrests occurred on Sunday nights.

Table 1 describes the 17 arrests in which a public AED was within 100 metres. Patient demographics and arrest characteristics are listed, as well as the EMS outcome of the arrest. Although the small sample size precludes formal analysis of these EMS outcomes, it is notable that return of spontaneous circulation was achieved in the field in only one of the seven cases of missed AED opportunity. In the seven of 17 cases in which return of spontaneous circulation was achieved in the field, bystander CPR was performed in all cases, and a bystander AED was utilised in six of the seven cases.

Discussion

This study sought to determine missed opportunities for PAD deployment and utilisation in OHCA. In a 5-year period in Orange County, we found 63% of public cardiac arrests did not have an AED within walking distance. When an AED was within walking distance of a public OHCA, it was not used 41% of the time. This was determined by mapping locations of OHCA and AED from collected databases. As this was a retrospective study, we could not adequately assess the reasoning for each missed opportunity, with the exception of two instances where an AED was behind a locked door after business hours.

We can speculate that the main reasons for underutilised deployment include lack of knowledge of PAD location and limited emergency training for lay public. Additionally, as the majority of public arrests did not have an AED within walking distance, we recommend that the guidelines for placement of PAD within high risk areas such as high density, schools, athletic facilities and religious institutions should be followed by leadership of these facilities. Private business should be encouraged to have PAD available 24/7 in case of an emergency. Overall, the missed opportunities underscore the need for greater integration of PAD programs into the local emergency response system and better advertising to the public where and how to access public AEDs.

Figure 3. Identification of OHCA with nearby AEDs and PAD utilisation

Age	Gender	Witnessed	Location	Initial rhythm	Bystander CPR	Bystander AED	Missed PAD opportunity	EMS response time (min)	EMS outcome
78	M	Yes, staff	Dialysis centre	VF	Yes	Yes	No	4	Field ROSC after EMS arrival
65	M	Yes, staff	Dialysis centre	Asystole	Yes	Yes	No	4	Termination on scene
71	F	Yes, staff	Dialysis centre	PEA	Yes	Yes	No	4	Transported in arrest
61	M	No	Hotel	PEA	Yes	No	Yes	6	Termination on scene
56	M	Yes, staff	City pool	VF	Yes	Yes	No	7	Field ROSC after EMS arrival
88	M	Yes, staff	Doctor's office	PEA	Yes	Yes	No	8	Transported in arrest
65	F	Yes, bystanders	Church	VF	No	No	Yes	4	Transported in arrest
5	F	No	Private residence	Asystole	No	No	Yes	6	Transported in arrest
54	F	Yes, staff	Dialysis centre	Sinus	Yes	Yes	No	6	ROSC before EMS arrival
54	F	Yes, staff	Dialysis centre	Sinus	Yes	Yes	No	6	ROSC before EMS arrival
56	M	Yes, bystanders	Street	Asystole	Yes	No	Yes	10	Transported in arrest
88	M	Yes, staff	Senior centre	PEA	Yes	Yes	No	5	Transported in arrest
86	F	Yes, bystanders	Apartment complex	PEA	No	No	Yes	4	Termination on scene
70	F	Yes, staff	Dialysis centre	PEA	Yes	Yes	No	3	Field ROSC after EMS arrival
Newborn	M	Yes, staff	Birth centre	'agonal'	Yes	No	Yes	9	Transported in arrest
66	M	Yes, family	Private residence	VT	Yes	No	Yes	5	Field ROSC after EMS arrival
74	M	Yes, staff	Health centre	Sinus	Yes	Yes	No	8	ROSC before EMS arrival

Table 1. OHCAs identified as having a nearby public automated external defibrillator
VF = ventricular fibrillation, VT = ventricular tachycardia, PEA = pulseless electrical activity, ROSC = return of spontaneous circulation

One specific barrier to this goal is that many states in the US do not require a registry of AEDs to be maintained, leading to many AEDs going unregistered (26). Similarly, Rea and colleagues in 2011 found that an AED registry with EMS systems did improve PAD deployment, but found that over half of OHCA had AEDs that were not registered (27). Up-to-date and maintained registries of AEDs integrated with local EMS systems may improve PAD deployment in OHCA if the caller is notified of the AED location (26,27). Other possible solutions to this problem exist, such as smartphone applications ('apps') that alert people to nearby OHCA and AEDs if they have voluntarily downloaded the app. This allows the crowdsourcing of PAD mapping. However, many of these applications require local emergency systems to pay annual licensing fees in order to allow lay rescuer notification. Thus, these systems are not ubiquitous, but have been implemented in some areas across the US (42-44). This strategy requires significant public investment but is certainly a possible method to combat PAD underutilisation. The 2015 update on guidelines for CPR and emergency cardiovascular care by the American Heart Association stated that 'it may be reasonable for communities to incorporate social media technologies that summon rescuers who are in close proximity to a victim of suspected OHCA', citing a Swedish study that found significantly increased rates of bystander CPR with mobile phone dispatch programs (45). Another strategy is for AED manufacturers to include built in beacon locators into their AEDs and create their own app for the public to locate this registry. There are many different makes and models of AEDs so this would require multiple manufacturers to coordinate. More research in lay rescuer notification is needed.

This study found that there was insufficient PAD coverage and accessibility, a topic that is widely discussed in the literature (20,23,33,38,46). About one-third of public OHCA in Orange County had AEDs available for use, consistent with Hansen's study of PAD in 2013 (25). Other studies also show much lower numbers of PAD deployment, such as a 1.74% deployment rate in Hampshire (47). According to Weisfeldt and colleagues, nearly 500 lives per year are saved with the use of bystander AEDs; however, could this number increase with better integration and notification of bystanders to where AEDs are located? (21). Although the greater access to AEDs may lead to an increase in missed opportunities without adequate integration into the emergency response system, overall greater accessibility still provides positive outcomes (20).

Lastly, the lack of AED accessibility to private residences is another topic highlighted by this study, as we found that 71% of OHCA occurred in private homes. The American Heart Association underscores the need for early defibrillation in the 'cardiac chain of survival', thus attempts at increasing the accessibility of AEDs to private households in the case of OHCA should be attempted. However, it is unclear if this

is cost-effective compared to interventions such as life vests for at-risk patients. Often, the first attempt at defibrillation in private residences is from devices by first responders. Prolonged response times without defibrillation do not have good outcomes. This problem is especially exacerbated for OHCA occurring in rural communities (48). Some agencies try to combat this by providing AEDs to law enforcement officials, but similar barriers to AED use exist with this method, such as prolonged response times (49). Another intervention under investigation is 'ambulance drones' that deliver an AED to private residences (50-52). There is a lack of literature surrounding the cost efficiency of 'ambulance drones', but perhaps the deployment of drones can improve AED deployment time in OHCA, whether they occur in public or in private residences. This method can also be used for public OHCA in which there are no AEDs to utilise (53). Barring other logistical considerations such as drone recovery and launch time, it is an intervention that should be explored.

Limitations

There are several limitations to this study. The use of retrospective data introduces imprecision in finding the exact location and address of OHCA and PAD. Also, one could argue that short EMS response times or an initial rhythm not amenable to defibrillation may not represent a truly missed need for a PAD program defibrillation. Nonetheless, our study attempted to identify times that a publicly available AED could have been prospectively considered for use, and was not. Additionally, our method does not consider vertical distances, which would add increased travel distance and time for a bystander to get to a nearby AED. Further study of vertical response and bystander AED usage is needed. Lastly, our study did not assess what the barriers were to PAD deployment or PAD utilisation by specific bystanders in the cases of missed opportunities. A better understanding of barriers to utilisation in this community would create an opportunity to make targeted interventions to increase future PAD utilisation.

Conclusion

This study found that there are missed opportunities for PAD deployment in OHCA. There is a need for better integration of PAD programs into local emergency response systems to enable fast and effective utilisation by public bystanders. With the increase in availability of PAD, underutilisation may be an unforeseen consequence. Further research into PAD underutilisation and ongoing education of the public are needed. More research in this domain should be done with attempts at reducing this discrepancy. Secondary findings of this study echo the current literature in the need for better education and access to AEDs in order to promote early defibrillation.

Conflict of interest

The authors declare no competing interests. Each author of this paper has completed the ICMJE conflict of interest statement.

Author contributions

JGW and JHB conceived the study. AJ, JL, WC, WW, JGW created the study databases, collected the data, and performed and supervised data entry. CC, JGW, FS, JHB performed and supervised data analysis. CC was the primary author of the manuscript, with input and editing from all authors. JGW takes responsibility for the study as a whole.

References

1. Mozaffarian D, Benjamin EJ, Go AS, et al, on behalf of the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics - 2015 update: a report from the American Heart Association. *Circulation* 2015;131:e128-32.
2. Centers for Disease Control and Prevention. 2017 Cardiac Arrest Registry to Enhance Survival (CARES) National Summary Report. 2017. Available at: <https://mycares.net/sitepages/aboutcares.jsp> [Accessed 31 July 2017].
3. Daya MR, Schmicker RH, Zive DM, et al. Resuscitation Outcomes Consortium Investigators. Out-of-hospital cardiac arrest survival improving over time: results from the Resuscitation Outcomes Consortium (ROC). *Resuscitation* 2015;91:108-15.
4. Neumar RW, Shuster M, Callaway CW, et al. Part 1: executive summary: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation* 2015;132(Suppl 2):S315-67.
5. Cummins RO, Ornato JP, Thies WH, Pepe PE. Improving survival from sudden cardiac arrest: the "chain of survival" concept. A statement for health professions from the Advanced Cardiac Life Support Subcommittee and the Emergency Cardiac Care Committee, American Heart Association. *ibid.* 1991;83:1832-47.
6. Stiell IG, Wells GA, De Maio VJ, et al. Modifiable factors associated with improved cardiac arrest survival in a multicenter basic life support/defibrillation system: OPALS Study Phase I results. *Ann Emerg Med* 1999;33:44-50.
7. Stiell IG, Wells GA, Field BJ, et al. Improved out-of-hospital cardiac arrest survival through the inexpensive optimization of an existing defibrillation program: OPALS study phase II. *JAMA* 1999;281:1175-81.
8. Stiell IG, Wells GA, Field BJ, et al. Advanced cardiac life support in out-of-hospital cardiac arrest. *N Engl J Med* 2004;351:647-56.
9. Valenzuela TD, Roe DJ, Cretin S, Spaite DW, Larsen MP. Estimating effectiveness of cardiac arrest interventions: a logistic regression survival model. *Circulation* 1997;96:3308-13.
10. Larsen MP, Eisenberg MS, Cummins RO, Hallstrom AP. Predicting survival from out-of-hospital cardiac arrest: a graphic model. *Ann Emerg Med* 1993;22:1652-8.
11. Waalewijn RA, de Vos R, Tijssen JG, Koster RW. Survival models for out-of-hospital cardiopulmonary resuscitation from the perspectives of the bystander, the first responder, and the paramedic. *Resuscitation* 2001;51:113-22.
12. Schober P, van Dehn FB, Bierens JJLM, Loer SA, Schwarte LA. Public access defibrillation: time to access the public. *Ann Emerg Med* 2011;58:241-7.
13. Winkle RA. The effectiveness and cost effectiveness of public-access defibrillation. *Clin Cardiol* 2010;33:396-9.
14. Caffrey SL, Willoughby PJ, Pepe PE, Becker LB. Public use of automated external defibrillators. *N Engl J Med* 2002;347:1242-7.
15. Gratton M, Lindholm DJ, Cambell JP. Public-access defibrillation: where do we place the AEDs? *Prehosp Emerg Care* 1999;3:303-5.
16. Reed DB, Birnbaum A, Brown LH, et al. Location of cardiac arrests in the public access defibrillation trial. *ibid.* 2006;10:61-7.
17. Mell HK, Sayre MR. Public access defibrillations and fire extinguishers: are comparisons reasonable? *Prog Cardiovasc Dis* 2008;51:204-12.
18. Weisfeldt ML, Kerber RE, McGoldrick RP, et al. Public access defibrillation. A statement for healthcare professions from the American Heart Association Task Force on automatic external defibrillation. *Circulation* 1995;92:2763.
19. Nichol G, Hallstrom AP, Kerber R, et al. American Heart Association Report on the Second Public Access Defibrillation Conference, April 17-19, 1997. *ibid.* 1998;97:1309-14.
20. Hallstrom A, Ornato JP, Weisfeldt ML, et al. Public Access Defibrillation Trial Investigators. Public access defibrillation and survival after out-of-hospital cardiac arrest. *N Engl J Med* 2004;351:637-46.
21. Weisfeldt ML, Everson-Stewart S, Sitlani C, et al. *ibid.* 2011;364:313-21.
22. Weisfeldt ML, Sitlani CM, Ornato JP, et al. Survival after application of automatic external defibrillators before arrival of the emergency medical system. *J Am Coll Cardiol* 2010;55:1713-20.
23. 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.
24. Cram P, Vijan S, Fendrick M. Cost-effectiveness of automated external defibrillator deployment in selected public locations. *J Gen Intern Med* 2003;18:745-54.
25. 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.

References (continued)

26. 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.
27. Rea TD, Blackwood J, Damon S, Phelps R, Eisenberg M. A link between emergency dispatch and public access AEDs: potential implications for early defibrillation. *Resuscitation* 2011;82:995-8.
28. De Maio VJ, Stiell IG, Wells GA, Spaite DW. Optimal defibrillation response intervals for maximum out-of-hospital cardiac arrest survival rates. *Ann Emerg Med* 2003;42:242-50.
29. Frank RL, Rausch MA, Menegazzi JJ, Rickens M. The locations of nonresidential out-of-hospital cardiac arrests in the city of Pittsburgh over a three-year period: implications for automated external defibrillator placement. *Prehosp Emerg Care* 2001;5:247-351.
30. Lerner EB, Billittier AJ, Newman MM, Groh WJ. Automated external defibrillator (AED) utilization rates and reasons fire and police first responders did not apply AEDs. *ibid.* 2002;6:378-82.
31. Sun C, Demirtas D, Brooks SC, Morrison LJ, Chan T. Overcoming spatial and temporal barriers to public access defibrillators via optimization. *J Am Coll Cardiol* 2016;68:836-45.
32. 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;120:510-7.
33. Bartimus HA, Rea TD, Eisenberg MS. Prevalence of automated external defibrillators at cardiac arrest high-risk sites. *Prehosp Emerg Care* 2004;8:280-3.
34. Rea TD, Olsufka M, Bemis B, et al. A population-based investigation of public access defibrillation: role of emergency medical services care. *Resuscitation* 2010;81:163-7.
35. Lerner EB, Fairbanks RJ, Shah MN. Identification of out-of-hospital cardiac arrest clusters using a geographic information system. *Acad Emerg Med* 2005;12:81-4.
36. Aufderheide T, Hazinski MF, Nichol G, et al. Community lay rescuer automated external defibrillation programs: key state legislative components and implementation strategies: a summary of a decade of experience for healthcare providers, policymakers, legislators, employers, and community leaders from the American Heart Association Emergency Cardiovascular Care Committee, Council on Clinical Cardiology, and Office of State Advocacy. *Circulation* 2006;113:1260-70.
37. The American Heart Association in collaboration with the International Liaison Committee on Resuscitation. Part 4: the automated external defibrillator: key link in the chain of survival. In: *Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care.* *ibid.* 2000;102(Suppl 8):I-60-76.
38. Becker L, Eisenberg M, Fahrenbruch C, Cobb L. Public locations of cardiac arrest: implications for public access defibrillation. *ibid.* 1998;97:2106-9.
39. Engdahl J, Herlitz J. Localization of out-of-hospital cardiac arrest in Goteborg 1994 – 2002 and implications for public access defibrillation. *Resuscitation* 2005;64:171-5.
40. Neumar RW, Barnhart JM, Berg RA, *ibid.* Implementation strategies for improving survival after out-of-hospital cardiac arrest in the United States: consensus recommendations from the 2009 American Heart Association Cardiac Arrest Survival Summit. *Circulation* 2011;123:2898-910.
41. Litwin PE, Eisenberg MS, Hallstrom AP, Cummins RO. The location of collapse and its effect on survival from cardiac arrest. *Ann Emerg Med* 1987;16:787-91.
42. Contra Costa County fire departments launch life-saving cell phone app. ABC7 San Francisco. Available at: <http://abc7news.com/archive/8986898/> [Accessed 23 July 2018].
43. PulsePoint.org | Allegheny County, Pittsburgh Announce Launch of Lifesaving Smartphone Application. Available at: www.pulsepoint.org/2016/07/07/allegheny-county-pittsburgh-announce-launch-of-lifesaving-smartphone-application/ [Accessed 23 July 2018].
44. Richmond (Va.) Implements PulsePoint Respond and PulsePoint AED. Public Safety Communications. 1460592000. Available at: <https://psc.apcointl.org/2016/04/14/richmond-va-implements-pulsepoint-respond-and-pulsepoint-aed/> [Accessed 23 July 2018].
45. 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.
46. Atkins DL. Realistic expectations for public access defibrillation programs. *Curr Opin Crit Care* 2010;16:191-5.
47. 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.
48. Portner ME, Pollack ML, Schirk SK, Schlenker MK. Out-of-hospital cardiac arrest locations in a rural community: where should we place AEDs? *Prehosp Disaster Med* 2004;19:352-5.
49. Mosesso VN, Newman MM, Ornato JP, et al. Law Enforcement Agency Defibrillation (LEA-D): proceedings of the National Center for Early Defibrillation Police AED Issues Forum. *Prehosp Emerg Care* 2002;6:273-82.
50. Nelson RD, Bozeman W, Collins G, et al. Mobile versus fixed deployment of automated external defibrillators in rural EMS. *Prehosp Disaster Med* 2015;30:152-4.
51. Van de Voorde P, Guatama S, Momont A, et al. The drone ambulance [A-UAS]: golden bullet or just a blank? *Resuscitation* 2017;116:46-8.
52. Pulver A, Wei R, Mann C. Locating AED enabled medical drones to enhance cardiac arrest response times. *Prehosp Emerg Care* 2016;20:378-89.
53. Boutillier JJ, Brooks SC, Janmohamed A, et al. Optimizing a drone network to deliver automated external defibrillators. *Circulation* 2017;135:2454-65.