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Clinical paper

Bystander automated external defibrillator application in non-shockable out-of-hospital cardiac arrest

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Abstract

Background: An increasing proportion of patients with OHCA present with non-shockable rhythms, among whom the benefit from AED application is not known.

Methods: We performed a retrospective analysis of adults with non-traumatic, public, bystander-witnessed, non-shockable OHCA occurring between 2005–2015 at 9 locations participating in the Resuscitation Outcomes Consortium. Non-shockable arrest was defined as when no shock was administered by a bystander applied AED and confirmed by the initial rhythm on EMS arrival. Outcomes were compared between patients with non-shockable OHCA in whom a bystander AED was or was not applied.

Results: Among 2809 patients with non-shockable public, witnessed OHCA, 8.4% had an AED applied. CPR was more often performed in the AED-applied group (99% vs. 51% of patients, $p < 0.001$). Among patients in whom an AED was not applied, 39.8% had any pre-hospital ROSC, 29.6% had a pulse at ED arrival and 11.1% survived to hospital discharge compared to 44.1%, 29.6% and 9.7%, respectively with AED application. After adjustment for the Utstein variables excluding bystander CPR, the OR for survival to hospital discharge for AED application was 0.90 (95% CI:0.57–1.42); when adjusted for the higher frequency of CPR in the AED group the OR was 0.92 (95% CI:0.57–1.47).

Conclusions: The application of an AED in non-shockable public witnessed OHCA was associated with a higher frequency of bystander CPR. The probabilities of pre-hospital ROSC, pulse at ED arrival, and survival to hospital discharge were not altered by the application of an AED.

Keywords: Automated external defibrillator, Cardiopulmonary resuscitation, Out-of-hospital cardiac arrest, Sudden cardiac arrest

Introduction

Most bystander-witnessed out-of-hospital cardiac arrests (OHCA) that occur in a public location present with a ventricular tachyarrhythmia that is treatable with electrical defibrillation.[1] Rapid defibrillation by a bystander-applied automated external defibrillator (AED) can improve both survival and functional outcome from OHCA.[2–7] However the impact of public access AEDs in non-shockable arrests is uncertain. These arrests, characterized by asystole and pulseless electrical activity, are not treatable by defibrillation, rather, the most efficacious interventions are early, high quality cardiopulmonary

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resuscitation (CPR)[8] and addressing treatment of the underlying cause.[9] In 2010, Chan et al. demonstrated that AED use in non-shockable arrest was associated with lower survival for in-hospital cardiac arrest.[10] This finding was theorized to be the result of delays or interruptions in CPR for automated rhythm checks and electrode placement. The role of AED application among non-shockable cardiac arrest in the out-of-hospital setting has not been rigorously investigated. Although, overall, AEDs improve outcome in public witnessed cardiac arrest, this effect may be due to a large benefit in the shockable arrests, which outweighs the potential harm associated with AED application among non-shockable arrests.

We hypothesized that AED application in non-shockable cardiac arrest in the out-of-hospital setting may improve survival given that rescuers are often laypersons in uncertain circumstances as opposed to medical professionals responding to a code alert. Therefore AED audible prompts may encourage layperson performance of bystander CPR and a pre-applied AED may facilitate arrest recognition and efficient transfer of care upon arrival of emergency medical services (EMS) responders. We tested this hypothesis in a population based cohort study of patients with non-shockable, public witnessed out-of-hospital cardiac arrest using the Resuscitation Outcomes Consortium (ROC) Epistry database.

Methods

Setting and participants

The ROC is an international clinical trials network that consists of 9 North American based regional centers, 6 in the United States (Dallas, TX; Seattle-King County, WA; Portland, OR; Milwaukee, WI; Pittsburgh, PA; Birmingham, AL) and 3 in Canada (Toronto, ON; Ottawa, ON; Vancouver, BC) with the purpose of conducting randomized trials on out-of-hospital cardiac arrest and life-threatening trauma. A clinical and data coordination center, located in Seattle WA, provides oversight of study design, data collection and quality control. The ROC Epistry: Cardiac Arrest is a population based multicenter epidemiologic registry of cardiac arrest care and outcomes that was implemented in parallel with the development of ROC clinical trials.

The rationale, design and implementation of ROC Epistry has been described previously.[11] Briefly, Epistry collected data on patient characteristics, interventions, and outcomes in non-traumatic EMS-evaluated out-of-hospital cardiac arrest. Data elements were defined by the study investigators in accordance with the Utstein criteria and other published literature. Quality control and protocol adherence were evaluated by ROC staff to maximize the validity and reproducibility of the data. All research activities were approved by each site's institutional review boards or other appropriate regulatory bodies and were conducted in accordance with local, state and federal requirements for human subjects research.

Design

This study used the ROC Epistry to conduct a retrospective, population-based, multicenter cohort study of patients with non-shockable public witnessed out-of-hospital cardiac arrest. Application of an AED by a bystander was the key intervention of interest and was pre-defined as a ROC Epistry data element. The primary outcome was survival to hospital discharge. The functional outcome of patients was recorded for a subset of patients with arrests occurring between 2010–2015 by trained study personnel from the patient medical record and evaluated using the modified Rankin Score.[12,13]

Definitions

As detailed previously,[11] a public setting arrest was defined as any arrest occurring in or on a street or highway, public building, place of recreation, industrial site or other public location. Witnessed arrest was defined as arrests in which the collapse of the patient was heard and/or seen by a bystander. A shockable rhythm was defined as pulseless ventricular tachycardia or ventricular fibrillation. Non-shockable arrest was defined as any arrest in which no shock was administered by either a bystander-applied AED or an EMS responder defibrillator. A favorable functional status was defined as a modified Rankin Score <3.

Inclusion and exclusion criteria

The study included all adults (>18 years of age) with non-traumatic out-of-hospital cardiac arrests occurring in public before EMS arrival, witnessed by a bystander and classified as non-shockable. We excluded cases in which the EMS provider witnessed the arrest as AED application by the public was not possible in this circumstance. In 16% of patients with a bystander-applied AED but no AED shock delivered, the initial rhythm on EMS arrival was shockable. These patients were excluded as we cannot rule out the possibility that the AED electrodes or wiring were applied incorrectly or that the bystander failed to press the "shock" button despite the presence of a shockable rhythm (Fig. 1).

Although the primary population for this study was public witnessed arrests we conducted a post-hoc analysis of an expanded population that included private and unwitnessed arrests to allow for additional comparison between our results and those of other studies. Furthermore, we analyzed the functional status of patients for the time period during which this data was routinely collected by ROC sites (2010–2015) for both the primary and expanded secondary populations.

Statistical analysis

We used descriptive statistics to evaluate categorical and continuous variables according to whether an AED was applied. We used multivariable logistic regression to determine the odds ratio of survival for patients with an AED application compared to those without AED application after accounting for potential confounding variables. Odds ratios were calculated using the sandwich form of the standard error. The adjusted model included age (18–39, 40–49, 50–59, 60–69, 70–79, 80–89, 90+ years), sex, bystander CPR, interval from 911 call received at dispatch to EMS arrival (<5, 5–9, 10–14, 15–19, 20+ min), and study site as covariates. The study site was reported (Table 1) with random letters to ensure anonymity of patients given the small number of patients in the AED cohort of the study. The primary analysis was also repeated with the exclusion of bystander CPR from the multivariate analysis. Analyses were conducted using commercially available statistical software (SAS 9.4 (SAS Institute Inc., Cary, NC, USA) and R 2.14.1 (R Foundation for Statistical Computing, Vienna, Austria).

Results

From 2005 to 2015 there were 2809 non-shockable public witnessed out-of-hospital cardiac arrests (Fig. 1). Among these, 236 (8.4%) had an

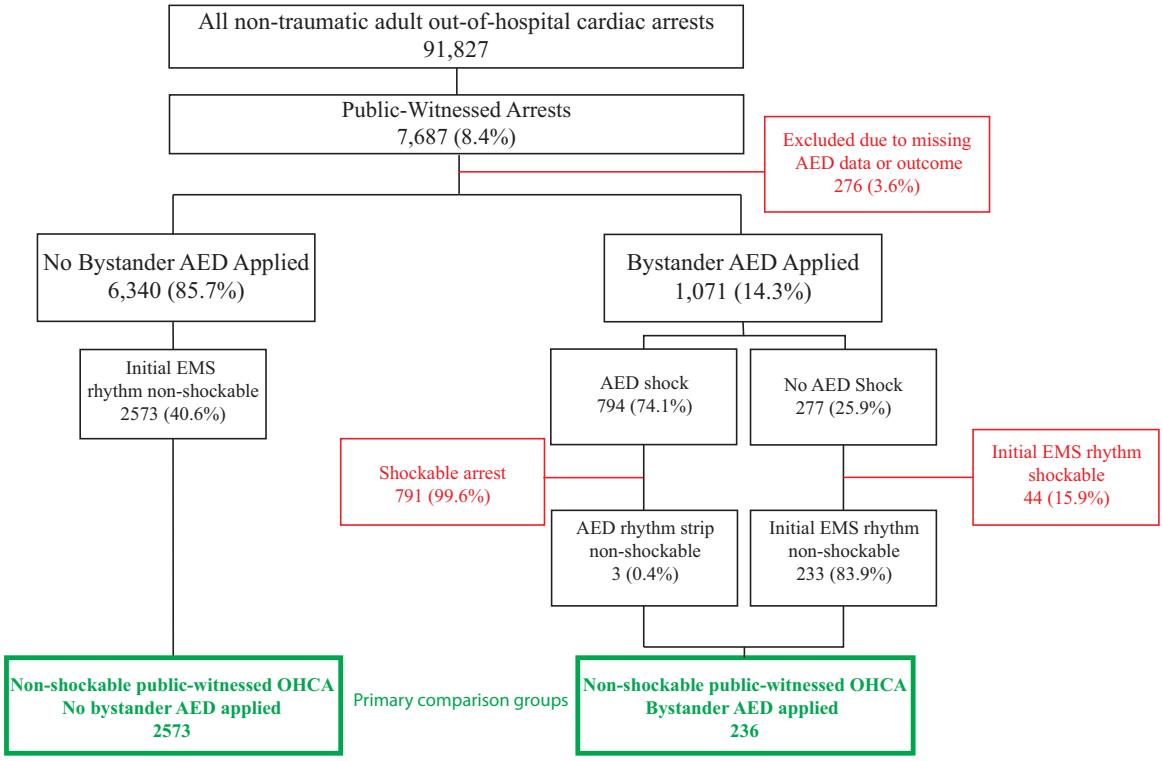

Fig. 1 – Patient inclusion and exclusion criteria.

AED applied by a bystander and 73% were male with no significant differences according to AED application status. Patients with an AED applied were significantly older that patients without an AED applied (mean age 66 for AED applied, 63 for no AED applied, p = 0.005). Patients with OHCA where an AED was applied were more likely to be in public buildings and places of recreation and less likely to be on streets or highways at the time of arrest. Four of the nine sites contributed 72% of the overall arrests and 79% of the AED applied arrests (Table 1).

Table 1 – Characteristics of non-shockable public, witnessed cardiac arrests.

		All N = 2809	No AED applied N = 2573	AED applied N = 236	p-Value
Age (years)	Mean (SD)	63 (16)	63 (17)	66 (15)	0.005
	Median (Q1, Q3)	64 (53, 76)	63 (52, 76)	67 (56, 77)	
Male	n (%)	2041 (73%)	1873 (73%)	168 (71%)	0.56
Location type					
Street/highway	n (%)	941 (33%)	914 (36%)	27 (11%)	<0.001
Public building	n (%)	321 (11%)	279 (11%)	42 (18%)	
Place of recreation	n (%)	283 (10%)	242 (9%)	41 (17%)	
Industrial place	n (%)	108 (4%)	96 (4%)	12 (5%)	
Other public	n (%)	1156 (41%)	1042 (40%)	114 (48%)	
Study site[a]					
Study site A	n (%)	96 (3%)	91 (4%)	5 (2%)	0.02
Study site B	n (%)	464 (17%)	432 (17%)	32 (14%)	
Study site C	n (%)	254 (9%)	243 (9%)	11 (5%)	
Study site D	n (%)	190 (7%)	181 (7%)	9 (4%)	
Study site E	n (%)	389 (14%)	351 (14%)	38 (16%)	
Study site F	n (%)	152 (5%)	140 (5%)	12 (5%)	
Study site G	n (%)	108 (4%)	96 (4%)	12 (5%)	
Study site H	n (%)	350 (12%)	311 (12%)	39 (17%)	
Study site I	n (%)	806 (29%)	728 (28%)	78 (33%)	

AED = automatic external defibrillator; min = minutes; CPR = cardiopulmonary resuscitation; EMS = emergency medical services; Q1 = first quartile; Q3 = third quartile.

[a] Each site represents a unique study site within ROC (eg, Seattle,WA).

Patients with OHCA in whom an AED was applied were more likely to receive bystander CPR (50% vs. 99%, $p < 0.001$). The mean time from emergency call to EMS arrival was 6.1 min overall, but significantly longer among patients in whom an AED was applied (6.8 vs. 6.0 min, p = 0.009) (Table 2). The initial rhythm on subsequent EMS arrival could be classified specifically as PEA or asystole in 83% of cases. In all, 25% of patients with non-shockable arrests were subsequently shocked by an EMS-applied defibrillator at some point during resuscitation, and did not differ between the study groups (22% AED applied vs. 26% no AED applied, p = 0.29).

The probability of pre-hospital ROSC did not differ between patients according to AED application (44.1% AED applied vs. 39.8% no AED applied, aOR 1.16 [95% CI: 0.86, 1.57]) nor did the frequency of patients with a pulse at ED arrival (29.6% AED applied vs. 29.6% no AED applied, aOR 1.03 [95% CI: 0.74, 1.43]). Similarly, survival to hospital discharge did not differ between patients according to AED application (9.7% AED applied vs. 11.1% no AED applied, p = 0.52). There was no evidence of survival difference after adjustment for potential confounders (adjusted OR = 0.92 (95% CI: 0.57,1.47) for AED versus no AED applied). When bystander CPR was excluded from the multivariate analysis the adjusted OR for survival was 0.90 (95% CI: 0.57, 1.42) (Table 3,Fig. 2). A subsequent analysis showed that bystander CPR was not independently associated with survival in this population (aOR = 1.05, (95% CI: 0.81, 1.35)) (Table 5).

In the post-hoc analysis with the population expanded to include private and unwitnessed arrests there were 67,260 out-of-hospital cardiac arrests that were non-shockable. The baseline patient and treatment characteristics for this population are available in the online only supplement (Tables S1, S2). In this population, bystander application of an AED was associated with a higher likelihood of survival to hospital discharge (4.5% for no AED applied vs 5.0% for AED applied). After adjusting for known covariates of survival this association was statistically significant (aOR 1.33, 95% CI 1.05–1.68) (Table 4).

The functional status of the patients at discharge was available for a proportion of the overall population. Data was available for 148 arrests with an AED applied and 1407 arrests without an AED applied. There was no significant association between AED application and favorable functional status as defined by a modified Rankin Score <3 (4.7% AED applied vs. 5.7% no AED applied, p = 0.86) (Table S3).

Discussion

Public AED use is an effective strategy among patients with shockable rhythm. The current study indicates that the majority of witnessed public setting arrests do present with a shockable arrest rhythm (60%) but that a substantial minority have a non-shockable arrest rhythm (40%). We observed that around 10% of these non-shockable patients received AED application prior to EMS arrival so a better understanding of AED use in this group is relevant to out-of-hospital resuscitation.

In this study, we did not observe a significant difference in pre-hospital ROSC, pulse at ED arrival and survival to hospital discharge between those patients who did and did not have an AED applied although those with an AED applied had a non-significantly lower survival rate to hospital discharge. Similarly, there was no significant difference in functional neurological outcome in arrests for which this information was available. Although the results do not indicate a survival benefit, we believe that the findings are consistent with the safety of AED application in out-of-hospital cardiac arrests presenting with a non-shockable rhythm. We hypothesized that much of the benefit to AED application in non-shockable arrest is improvement in the incidence and quality of bystander CPR. Our study was complicated, therefore, by the unexpected finding that bystander CPR was not associated with survival in this population. Furthermore, the application of an AED was significantly associated with survival to hospital discharge in a post-hoc analysis with the patient population expanded to include private and unwitnessed arrests. Although this finding is intriguing, caution should be used in the interpretation of this post-hoc analysis of a secondary population. Additional research is

Table 2 – Treatment of non-shockable public, witnessed cardiac arrests.

		All N = 2809	No AED applied N = 2573	AED applied N = 236	p-Value
Bystander CPR					
Yes	n (%)	1524 (54%)	1291 (50%)	233 (99%)	<0.001
No	n (%)	1285 (46%)	1282 (50%)	3 (1%)	
EMS time from 911 call to arrival (min)	Mean (sd)	6.1 (3.5)	6.0 (3.4)	6.8 (4.2)	0.01
	Median (Q1, Q3)	5.4 (4.0, 7.1)	5.3 (4.0, 7.0)	5.8 (4.2, 8.4)	
Epinephrine	n (%)	2258 (81%)	2060 (81%)	198 (84%)	0.23
Dose in milligrams	mean (sd)	3.6 (2.1)	3.6 (2.1)	3.8 (2.2)	0.14
Any AED shock	n (%)	3 (0%)	0 (0%)	3 (1%)	n/a
Any EMS shock	n (%)	710 (25%)	657 (26%)	53 (22%)	0.29
EMS shock within 3 min of EMS vehicle arrival	n (%)	32	32	0	n/a
Initial EMS rhythm					0.02
PEA	n (%)	1177 (42%)	1066 (41%)	111 (47%)	
Asystole	n (%)	1139 (41%)	1045 (41%)	94 (40%)	
No shock/no strip	n (%)	350 (12%)	333 (13%)	17 (7%)	
Cannot determine	n (%)	66 (2%)	64 (2%)	2 (1%)	
Missing	n (%)	77 (3%)	65 (3%)	12 (5%)	

AED = automatic external defibrillator; min = minutes; CPR = cardiopulmonary resuscitation; EMS = emergency medical services; Q1 = first quartile; Q3 = third quartile.

Table 3 – Outcome of non-shockable public, witnessed cardiac arrests.

		All N = 2809	No AED applied N = 2573	AED applied N = 236	OR (95% CI)	aOR[a] (95% CI)	aOR[b] (95% CI)
Any pre-hospital ROSC	n (%)	1129 (40.2%)	1025 (39.8%)	104 (44.1%)	1.19 (0.91, 1.56)	1.16 (0.86, 1.57)	1.18 (0.88, 1.58)
Pulse on ED arrival	n (%)	797 (29.6%)	729 (29.6%)	68 (29.6%)	1.00 (0.75, 1.34)	1.03 (0.74, 1.43)	1.01 (0.73, 1.38)
Survival to hospital discharge	n (%)	309 (11.0%)	286 (11.1%)	23 (9.7%)	0.86 (0.55, 1.35)	0.92 (0.57, 1.47)	0.90 (0.57, 1.42)

[a] Adjusted for age, sex, year, bystander CPR, location, EMS Response Time.
[b] Adjusted for age, sex, year, location, EMS Response Time.

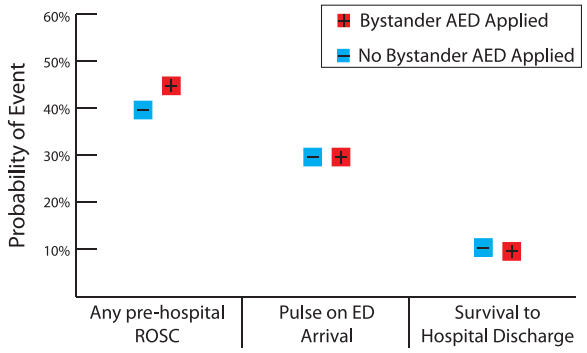

Fig. 2 – Frequency of the pre-specified outcomes according to bystander AED application.

necessary to identify the unique characteristics of the studied population that nullifies the benefits of bystander CPR and the potential benefit of AED application.

In contrast to a prior study from the in-hospital setting that observed 3% lower survival when an AED was applied (16.3% vs. 19.3%), we observe a smaller not statistically significant difference in survival between patients who had an AED applied versus those who did not in non-shockable arrest in the out-of-hospital setting (1.4% difference, 9.7% vs. 11.1% with an aOR with wide confidence intervals). This difference in results may be explained by the distinct circumstances and experiences of rescuers between the two settings. For example, hospitalized patients are not wearing many layers of clothes which require removal for effective resuscitation. In out-of-hospital arrest, in contrast, EMS responders can rapidly begin resuscitation efforts when a bystander has removed clothing and applied pads prior to EMS arrival. In addition, it is clear that CPR interruption has an inverse relationship to survival with several studies noting a survival advantage to keeping rhythm and pulse checks as short as possible.[14,15] Many AEDs provide instructions to initiate and resume CPR following rhythm checks. The importance of this AED function is supported by studies of simulated cardiac arrest which found that the rate of CPR initiation and the time to CPR initiation was associated with the clarity and detail of auditory AED instructions.[16,17] Furthermore, we are encouraged by recent efforts to provide video CPR instruction and real-time coaching on CPR quality via the AED.[18] We also note that many AEDs are in enclosures that automatically trigger an emergency response when they are opened. Furthermore, AEDs located near security desks in buildings may allow bystanders to direct the security guard to guide the EMS response to the appropriate location.

Table 4 – Outcome of all non-shockable out of hospital cardiac arrests.

		All N = 67,260	No AED applied N = 65,573	AED applied N = 1687	OR (95% CI)	aOR[1] (95% CI)	p-Value (adjusted model)
Any prehospital ROSC	n (%)	20,066 (29.8%)	19,507 (29.8%)	559 (33.1%)	1.17 (1.06, 1.30)	1.23 (1.11, 1.37)	<0.001
Pulse on ED arrival	n (%)	13,428 (20.5%)	13,045 (20.4%)	383 (23.2%)	1.18 (1.05, 1.32)	1.24 (1.09, 1.40)	<0.001
Survival to hospital discharge	n (%)	3062 (4.6%)	2978 (4.5%)	84 (5.0%)	1.10 (0.88, 1.38)	1.33 (1.05, 1.68)	0.02

[1] Adjusted for age, sex, year, bystander CPR, location, EMS Response Time.

Table 5 – Impact of bystander CPR on survival to hospital discharge.

		All N = 2809	No bystander CPR +/− AED N = 1285	Bystander CPR +/− AED N = 1524	OR (95% CI)	aOR[a] (95% CI)
Survived to hospital discharge	N (%)	309 (11%)	144 (11%)	165 (11%)	0.96 (0.76, 1.22)	1.05 (0.81, 1.35)

[a] Adjusted for age, sex, year, location, EMS Response Time.

The study of bystander interventions in resuscitation is challenging given the unexpected and uncontrolled nature of the event. Hence cohort studies, often performed retrospectively, provide valuable information and insight. As with all retrospective cohort studies, however, there may be unmeasured aspects of care that may confound our results. Responders who know to apply an AED may perform higher quality CPR or recognize cardiac arrest and call for EMS more rapidly. Although ROC pioneered the evaluation of CPR quality by EMS providers there is no existing capacity to measure bystander CPR quality (we are encouraged by recent AED designs that provide real-time feedback on CPR quality via built in pressure sensors). Furthermore, bystander estimation of time from collapse to 911 call are neither accurate nor precise.[19] We chose to include only witnessed arrests in the primary population as this population has the most homogenous time from collapse to initiation of resuscitation efforts. Unwitnessed arrests may have pulseless times for which resuscitation efforts are futile.

An additional consideration in this study is that participation in ROC was a competitive process; ROC sites may be higher performing in cardiac arrest care, which could modify the benefits of AED application and could limit the generalizability of these results. Analysis of populations and EMS systems participating in ROC, however, demonstrates substantial variation across ROC sites with regard to urban or rural environment, baseline patient and treatment characteristics as well as outcomes.[20,21]

We went to great lengths to ensure our studied population was non-shockable. For example, we excluded 44 patients with an AED application, no shock and with an initially shockable EMS rhythm. This excluded group had a higher probability of survival than the included population suggesting they may have been shockable arrests. Despite this exclusion, there is still the potential that a small proportion of patients that we deemed to have a non-shockable arrest were in fact shockable but the bystander did not press the “shock” button on the defibrillator. This number is likely to be small as over 87% of arrests with a bystander AED applied were confirmed to be PEA or asystole on EMS arrival.

Patients presenting with shockable out-of-hospital cardiac arrest are indistinguishable from those with a non-shockable arrest before application of an AED. Use of the AED is life-saving when the cardiac arrest is due to a shockable arrhythmia, whereas our results indicate no specific survival benefit nor adverse risk among those with non-shockable cardiac arrest. Taken together, the application of an AED in this combined population is thus likely to save more lives overall, making efforts to increase access to AEDs in the out-of-hospital setting a worthy goal. We are encouraged by the range of strategies such as the delivery of AEDs by drones,[22–24] mobile applications to link trained responders to AEDs,[25,26] and more portable AEDs. Additional innovations are needed to advance resuscitation specifically in patients with non-shockable arrest.

Conflict of interest

The authors have no conflicts to disclose.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resuscitation.2019.02.007.

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