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Public Access Defibrillation: Great benefit and potential but infrequently used☆

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ABSTRACT

Background: In Copenhagen, a volunteer-based Automated External Defibrillator (AED) network provides a unique opportunity to assess AED use.

We aimed to determine the proportion of Out-of-Hospital Cardiac Arrest (OHCA) where an AED was applied before arrival of the ambulance, and the proportion of OHCA-cases where an accessible AED was located within 100 m. In addition, we assessed 30-day survival.

Methods: Using data from the Mobile Emergency Care Unit and the Danish Cardiac Arrest Registry, we identified 521 patients with OHCA between October 1, 2011 and September 31, 2013 in Copenhagen, Denmark.

Results: An AED was applied in 20 cases (3.8%, 95% CI [2.4 to 5.9]). Irrespective of AED accessibility, an AED was located within 100 m of a cardiac arrest in 23.4% ($n = 102$, 95% CI [19.5 to 27.7]) of all OHCAs. However, at the time of OHCA, an AED was located within 100 m and accessible in only 15.1% ($n = 66$, 95% CI [11.9 to 18.9]) of all cases.

The 30-day survival for OHCA with an initial shockable rhythm was 64% for patients where an AED was applied prior to ambulance arrival and 47% for patients where an AED was not applied.

Conclusions: We found that 3.8% of all OHCAs had an AED applied prior to ambulance arrival, but 15.1% of all OHCAs occurred within 100 m of an accessible AED. This indicates the potential of utilising AED networks by improving strategies for AED accessibility and referring bystanders of OHCA to existing AEDs.

1. Introduction

Out-of-hospital cardiac arrest (OHCA) is a significant health problem associated with cardiovascular disease, which is the leading cause of sudden death.[1,2] Early defibrillation is essential to increase survival and the use of publicly accessible Automated External Defibrillators (AED) has been shown to increase the chances of survival up to 74%.[3–9] Despite initiatives to disseminate AEDs in public settings, the proportion of OHCA-victims defibrillated prior to arrival of the Emergency Medical Services (EMS) is reported to be less than 3% and a real opportunity to save lives is missed.[9–11]

The European Resuscitation Council and the American Heart Association recommend Public Access Defibrillation (PAD) programmes, but the deployment and registration of AEDs is often random and poorly organized, with no available information on location and accessibility, impeding use of AEDs by bystanders and linkage to the Emergency Medical Dispatch Centre (EMD). In Copenhagen, the capital of Denmark, a volunteer-based AED network has been established with validated information about AED location and accessibility. The network is linked to the EMD to enable guidance to nearest accessible AED in case of cardiac arrest. This provides a unique opportunity to assess the use, effects, and coverage of PAD as the network also allows systematic collection of data from applied AEDs.

In this study, we aimed to determine the proportion of OHCA-cases where an AED was applied prior to arrival of the ambulance

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and the proportion of OHCA-cases where the EMD referred bystanders to an AED. In addition, we sought to determine the proportion of OHCA-cases where an accessible AED was located within 100 m at the time of the cardiac arrest. Finally, we sought to evaluate characteristics and survival of OHCA-victims according to use of an AED.

2. Methods

2.1. Study setting

Copenhagen is the capital of Denmark, and the city centre comprises 94.9 km^2 with a population of 661,461 people.

The EMS in Copenhagen is a 2-tiered system comprising ambulances providing life support including use of defibrillators, and physician-staffed mobile emergency care units providing additional advanced life support. In the event of a cardiac arrest, both tiers of response are activated simultaneously. Data from each cardiac arrest are systematically and prospectively recorded by the physician at the scene and entered into a database maintained by the EMS in Copenhagen. Additionally, ambulance personnel are required to complete documentation for the National Danish Cardiac Arrest Registry for every resuscitation-attempted OHCA.

2.2. AED network

In 2007, the private foundation TrygFonden established an online network (http://www.hjertestarter.dk/Service-Pages/InEnglish) in which registration of both private and public AEDs is voluntary but recommended by the Danish Health and Medicines Authority and AED-vendors. The network provides detailed information about AED location (exact address) and accessibility, including hours when the AED is available, as described in detail elsewhere.[12] The EMDs across the country have implemented an IT-solution based on the AED network, enabling them to refer a bystander to the nearest accessible AED in the event of suspected OHCA. When an emergency call is received and the location is determined, the medical dispatcher is provided with a map showing the accessible AEDs within 100 m, thus enabling the dispatcher to refer a bystander to the nearest AED. If only one bystander is present, the dispatcher can choose to contact the AED location and have the AED brought to the scene of the cardiac arrest. When an AED is referred to by the dispatcher, an e-mail is automatically generated and sent to the network enabling them to unsubscribe the AED until in place again. Every case is followed up by an e-mail or a telephone call to the person listed as responsible for the AED in the network, thereby validating the use of the AED related to an OHCA. On January 2014, 850 AEDs in the city centre of Copenhagen were registered on the webpage.

Systematic follow-up of AEDs applied by bystanders in Copenhagen began in 2011 as part of a project on systematic downloading of AED data.[13] Each time an AED is applied by a bystander prior to arrival of the ambulance, the AED is brought to the EMD in Copenhagen in order to retrieve the stored data. The data are transmitted to the admitting hospital and the AED is returned to the owner.

2.3. Study population and data collection

This observational study evaluated the use and effects of PAD in the city centre of Copenhagen from October 1, 2011 through September 31, 2013. A cardiac arrest was defined according to the Utstein criteria for laypersons and ambulance personnel.[14] All cases of OHCA were included in the final analysis when a clinical condition of cardiac arrest resulted in resuscitation efforts by either bystanders or ambulance personnel. We excluded cardiac arrests witnessed by ambulance personnel as this study focused on PAD. Reporting was done in accordance with the Utstein template for reporting OHCA.[14]

For this study we included information on date, time, location of arrest (home vs. public location, the latter defined as all areas accessible to the general public), exact address of cardiac arrest, witnessed or not, whether the bystander performed cardio pulmonary resuscitation (CPR), defibrillated the victim or both, first recorded cardiac rhythm, ambulance response time (interval between call to the EMD and ambulance arrival), survival to hospital, and 30-day survival. Information regarding referral of bystanders to the nearest accessible AED by the EMD was collected from the online AED network. Data regarding use of AEDs (defined as AED applied to a patient prior to ambulance arrival) were obtained from the EMD and validated through prehospital medical records. Information on 30-day survival was obtained from the Danish Civil Registration System, which assigns all Danish citizens a civil registration number, a unique personal identification number.

Exact geographical location of OHCAs and AEDs was determined using a geographic information system (QGIS, http://www.qgis.org/en/site). Each location was geocoded to the street level based on the address of the incident and it was verified that each cardiac arrest occurred in the city centre of Copenhagen. The geocoding process assigns a latitude and longitude coordinate to each address. An AED was considered to cover an area within 100 m, based on the estimate that an AED within that range could be transported by bystanders to the victim within 1.5 min, in accordance with the American Heart Association recommendations.[15]

2.4. Ethics

The study, and the processing of personal data, was approved by the Danish Health and Medicines Authority (J. nr. 3-3015-560/1) and the Danish Data Protection Agency (J. nr. 30-1223). Ethical approval is not required for registry-based studies in Denmark.

2.5. Statistics

Continuous variables are presented as median with their associated inter quartile range [IQR]. A Mann–Whitney test was used for comparisons between the groups. Categorical data are reported as absolute number with proportion and comparisons were done using Fisher's exact test. All analyses were performed using the SAS Enterprise Guide statistical software package, version 6.1 (SAS Institute Inc., Cary, NC, USA). For all analysis, a 2-sided value of $p < 0.05$ was considered statistically significant.

3. Results

A total of 2075 cases of OHCA were recorded by the mobile emergency care unit in the city centre of Copenhagen during the study period. Of these, 1476 cases were excluded because resuscitation was not attempted. Five OHCA-cases, which were not registered with the EMD, were found in the Danish Cardiac Arrest Registry. We identified 604 OHCA-victims, in whom resuscitation was attempted, corresponding to an all-cause OHCA incidence of 46 OHCA per 100,000 person years.

For further analysis, we included 521 resuscitation-attempted OHCAs as 83 cases (mainly EMS-witnessed OHCAs) were excluded (Fig. 1).

An AED was applied prior to ambulance arrival in 20/521 (3.8%, 95% CI [2.4 to 5.9]) cases and 13/521 (2.5%, 95% CI [1.3 to 4.2]) OHCA-victims were defibrillated by an AED.

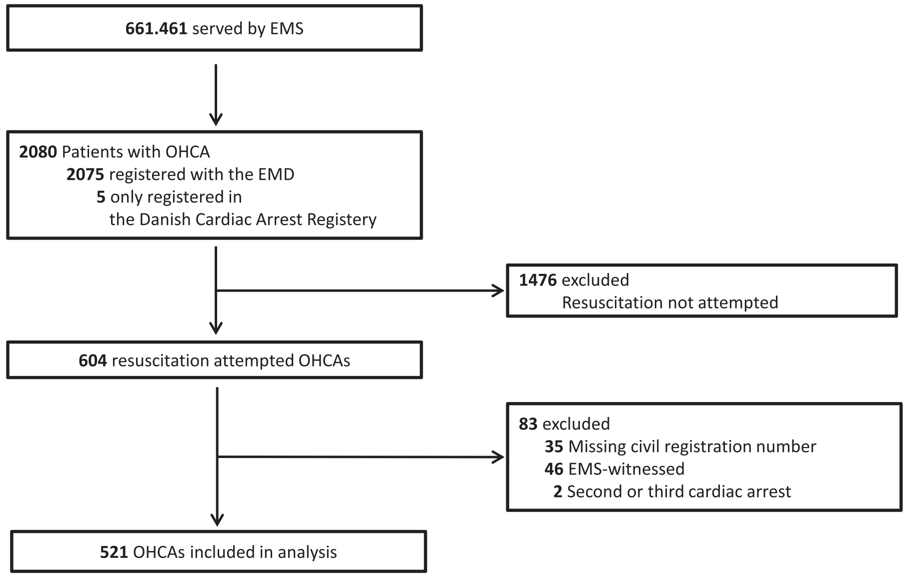

Fig. 1. Patient flow, October 1, 2011–September 31, 2013.

A total of 22 publicly accessible AEDs in the city centre of Copenhagen had ECG-data downloaded, but two patients did not have OHCA.

3.1. Characteristics of OHCA-victims

OHCA-cases who had an AED applied prior to ambulance arrival occurred significantly more often in public places (79% vs. 32%, $p \le 0.0001$) and they had a significantly higher proportion of bystander CPR (95% vs. 60%, $p = 0.0014$) and initial shockable rhythm (74% vs. 27%, $p \le 0.0001$) (Table 1). The proportion of bystander witnessed cardiac arrest and the ambulance response time were not significantly different, nor was there any significant differences in age or sex according to AED application. There were no differences in the proportion of OHCA-cases where an AED was applied according to the time of day.

3.2. AED-referral

Bystanders were referred to an AED by the EMD in 20 cases but an AED was only applied in six of these (30%) cases prior to ambulance arrival. In 14 cases, an AED was retrieved spontaneously by a bystander and applied to an OHCA-victim prior to ambulance arrival. There were no differences in patient characteristics and survival according to AED-reference (Table 2).

3.3. AED coverage and potential

Exact geographical location of 436 (84%) OHCAs was successfully determined. Irrespective of AED accessibility, an AED was located within 100 m of a cardiac arrest in 23.4% ($n = 102$, 95% CI [19.5 to 27.7]) of all OHCAs. At the time of cardiac arrest, an AED was located within 100 m and accessible in 15.1% ($n = 66$, 95% CI [11.9 to 18.9]) of all cases, but only 10.6% ($n = 7$, 95% CI [4.9 to 20.6]) of these had an AED applied.

In 13 cases, an AED was retrieved more than 100 m from the location of the cardiac arrest.

Accordingly, there were 59 OHCA-cases (11.3% of all OHCA, 95% CI [8.7 to 14.4]) where an AED could have been referred to by the EMD and applied prior to ambulance arrival.

3.4. Outcome

The 30-day survival for non-shockable OHCA was 20% for patients where an AED was applied prior to ambulance arrival and 9% for patients without an AED applied, $p = 0.37$. For OHCA with an initial shockable rhythm 30-day survival was 64% for patients with an AED applied and 47% for patients without an AED applied, $p = 0.26$ (Table 3).

(Table 3)

4. Discussion

In this study of a volunteer-based AED network, linked to the EMD, we found that 3.8% of all OHCAs had an AED applied prior to ambulance arrival. Almost every fourth OHCA had an AED within 100 m, however, the AED was only accessible at the time of cardiac arrest in 15.1% of the cases and only 10.6% of these had an AED applied. The EMD referred a bystander to the nearest accessible AED in 2.3% of all OHCA-cases. OHCA with an AED applied prior to ambulance arrival occurred more often in public locations, these patients received more often bystander CPR and they had a larger proportion of initial shockable rhythm.

The main strength of this study is that we describe several aspects of the use of a volunteer-based AED network with validated information on location and accessibility. Thus, we were able to describe independent retrieval and use of AEDs by bystanders, AED coverage, AED use by bystanders through EMD-referral, and ECG-data from applied AEDs. Most PAD studies only report data from shockable OHCAs thereby probably underestimating the use of AEDs.[5,16]

The potential of PAD in the city centre of Copenhagen was assessed through identification of all accessible AEDs within 100 m from the OHCA.

Several limitations must be mentioned. AED placement is decided solely by the AED owner and accordingly, the AED distribution is random. This study does not allow any changes in the locations of the AEDs and is therefore not designed for analysing AED placement and coverage, but rather for assessing the probability of having a nearby AED accessible in case of OHCA. Regarding EMD-reference of AEDs, the linkage between a referral and an OHCA-victim presents a challenge, as it is not registered when the dispatcher refers to an AED. The only information available was

Table 1
Out-of-hospital cardiac arrest in Copenhagen from October 1, 2011 through September 31, 2013. AED: Automated External Defibrillator, IQR: inter quartile range, CPR: Cardiopulmonary Resuscitation.

	AED applied prior to ambulance arrival (n = 20)[*]	AED not applied prior to ambulance arrival (n = 501)[*]	p Value
Age, median (IQR), y	73 (65–82)	67 (54–79)	0.34
Men, n (%)	12 (80.0)	301 (61.8)	0.18
Time of day[a]			0.49
Daytime, n (%)	9 (45.0)	236 (48.1)	
Evening, n (%)	9 (45.0)	162 (33.0)	
Night time, n (%)	2 (10.0)	93 (18.9)	
Public location, n (%)[b]	15 (79.0)	117 (32.2)	<0.0001
Response time, median (IQR), (min)[c]	5 (4–6)	5 (4–7)	0.29
Bystander witnessed, n (%)	15 (79.0)	224 (61.7)	0.15
Bystander CPR, n (%)	18 (94.7)	219 (60.3)	0.0014
Shockable rhythm, n (%)[d]	14 (73.7)	98 (27.0)	<0.0001

[*] Number of patients with missing value for the variables bystander witnessed, bystander CPR and public location: "AED applied prior to ambulance arrival" n = 1 and "AED not applied prior to ambulance arrival" n = 138.
[a] Daytime, evening and night time defined as 8 am to 3:59 pm, 4 to 11:59 pm, and midnight to 7:59 am.
[b] Public location defined as all areas accessible to the general public all hours all day.
[c] Interval between call to the EMS and ambulance arrival.
[d] First recorded rhythm.

Table 2
AEDs applied prior to ambulance arrival in Copenhagen from October 1, 2011 through September 31, 2013. EMD: Emergency Medical Dispatch Centre, IQR: inter quartile range, CPR: cardiopulmonary resuscitation.

	Referred by EMD (n = 6)	Not referred by EMD (n = 14)[*]	p Value
Age, median (IQR), y	73 (68–73)	73 (65–83)	0.62
Men, n (%)	4 (80.0)	7 (77.8)	1.0
Time of day[a]			0.35
Daytime, n (%)	4 (66.7)	5 (38.5)	
Evening and night time n (%)	2 (33.3)	8 (61.5)	
Public location, n (%)[b]	6 (100)	9 (69.2)	0.26
Response time, median (IQR), (min)[c]	4 (3–5)	5 (4–5)	0.25
Bystander witnessed, n (%)	5 (83.3)	10 (76.9)	1.0
Bystander CPR, n (%)	6 (100)	12 (92.3)	1.0
Shockable rhythm, n (%)[d]	5 (83.3)	9 (69.2)	1.0
30-Day survival, n (%)			
Non-shockable rhythm[e]	0 (0)	1 (20.0)	1.0
Shockable rhythm[f]	5 (71.4)	10 (83.3)	0.6

[*] Number of patients with missing value for the cardiac arrest-related variables: bystander witnessed, bystander CPR and public location n = 1.
[a] Daytime, evening and night time defined as 8 am to 3:59 pm, 4 to 11:59 pm, and midnight to 7:59 am.
[b] Public location defined as all areas accessible to the general public all hours all day.
[c] Interval between call to the EMS and ambulance arrival.
[d] First recorded rhythm.
[e] Non-shockable rhythm: Asystole or pulseless electrical activity.
[f] Shockable rhythm: ventricular fibrillation or pulseless ventricular tachycardia.

the location of AED and the time of reference. In this study, almost half of the referred AEDs could not be connected to an OHCA-case, which means that we have no knowledge of the nature of these referrals, or if the case was in fact an OHCA.

Additionally, we could only include information about AEDs with downloaded ECG-data and AEDs may have been applied without any ECG data being retrieved if the AED was not brought to the EMD after OHCA.

In Denmark, a nationwide study reports that 2.2% of all OHCA-cases were defibrillated prior to ambulance arrival in 2010.[11] We found an increased use of PAD, which might reflect several initiatives taken to raise survival after OHCA in Denmark during recent years including; implementation of mandatory resuscitation training in elementary schools and when acquiring a driver's licence, improving the telephone guidance to bystanders witnessing a cardiac arrest by implementation of health care professionals at the EMDs, and finally there has been a large increase in the number of public accessible AEDs.[11,12] Furthermore, we report AED use in the city centre of Copenhagen where AED coverage is higher than in more rural parts of the country. A study conducted on the Danish rural island of Bornholm showed that an AED was applied to an OHCA-victim in 10% of all OHCA-cases after an intervention comprising mass education in basic life support (BLS) and a television campaign.[17] The same study group showed that the willingness

Table 3
Outcome in OHCA patients in the city centre of Copenhagen 2013 from October 1, 2011 through September 31, 2013. OHCA: out-of-hospital cardiac arrest, AED: Automated External Defibrillator.

	AED applied prior to ambulance arrival	AED not applied prior to ambulance arrival	p Value
30-Day survival, n (%)			
Non-shockable rhythm[a]	1 (20%, 95% CI [0.5–72])	23 (9%, 95% CI [613])	0.37
Shockable rhythm[b]	9 (64%, 95% CI [35–87])	46 (47%, 95% CI [37–57])	0.26

[a] Non-shockable rhythm: Asystole or pulseless electrical activity.
[b] Shockable rhythm: ventricular fibrillation or pulseless ventricular tachycardia.

to use an AED increased significantly following the intervention, suggesting a way of creating awareness through education and information thereby increasing the use of PAD, as also described in other studies.[18–21]

Several aspects should be considered to further improve AED use. Since most cardiac arrests occur in residential areas, first responder programs may enhance PAD. Studies in Holland and Sweden have demonstrated high survival rates in association with structured AED programs as well as spread of unregulated AEDs.[22,23] Nearby lay-first responders, as part of a structured AED program, are dispatched through a text-message, thereby shortening time to defibrillation.[24,25] In addition, firefighters equipped with AEDs can be dispatched in the event of OHCA and this has been shown to increase survival.[26]

Linkage between the AED-network and the EMD is essential but there may be a mismatch between the time of cardiac arrest and the accessibility of the AEDs.[27]

Finally, identification of OHCA by the dispatcher represents a challenge in itself in order to refer a bystander to an AED.[28,29]

Means to increase AED utilisation should target public awareness of the AED network and the location of the AEDs, CPR and AED training, and further development of the existing AED network and linkage to the EMD with special attention on placing AEDs outside, providing accessibility at all times.

Two studies assessing the AED coverage of public OHCA in the city centre of Copenhagen between 1994 and 2011 showed AED coverage of 28.8% of all public OHCAs regardless of AED accessibility and an increase in AED coverage from 2.7% to 32.6% over a 5-year period, respectively.[12,27] We found a slightly smaller AED coverage of OHCA, most likely due to the fact that we included OHCAs, which happened in private homes.

We found no differences in patient characteristics and outcomes according to EMD-reference, but we only included OHCAs in an urban area where EMS response time is relatively short. Reference to nearby AEDs might have greater impact in rural areas with longer response time. Initiatives should be taken to optimize EMD-reference to nearby AEDs and to register referred AEDs in connection to OHCA-victims. Additionally, initiative should be taken to enhance retrieval of all applied AEDs.

Due to the small number of observations in this study, we were not able to detect a significant increase in survival when laypersons use an AED. However, the tendency towards an increase in 30-day survival is important as survival rates after OHCA in general are low.[2,3,30] The association between PAD and survival is in accordance with other studies.[5,7,16]

There may be other reasons for the tendency towards a high survival rate. First, other studies have shown that a high proportion of publicly accessible AEDs are placed in sports facilities where victims in general may be healthier.[4,27] Second, bystanders at these facilities are more likely to be trained to perform BLS as courses are often offered by the sports clubs and the AED vendors. We are aware that in order to correlate AED use and survival, it would have been relevant to perform an analysis with adjustments for confounding factors such as bystander CPR however, this was not possible due to the small proportion of OHCA with an AED applied before ambulance arrival.

We found a significantly higher proportion of an initial shockable rhythm if an AED was applied prior to ambulance arrival. This is important, since the prevalence in general is only approximately 25%, which could potentially jeopardize the concept of PAD.[31–33] Our findings is in accordance with another study conducted in Copenhagen which recently showed that publicly accessible AEDs detected an initial shockable rhythm in 55% of OHCA-cases compared with only 27.6% in the cases where the initial rhythm was detected by the EMS.[13]

5. Conclusion

We found that 3.8% of all OHCAs had an AED applied prior to ambulance arrival, but 15.1% of all OHCAs occurred within 100 m of an accessible AED. This indicates the potential of utilising AED networks by improving strategies for AED accessibility and referring bystanders of OHCA to existing AEDs.

Conflict of interest statement

No conflicts reported.

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