Use and benefits of public access defibrillation in a nation-wide network

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A B S T R A C T

Background: Automated External Defibrillators (AEDs) are known to increase survival after out-of-hospital cardiac arrest (OHCA). The aim of this study was to examine the use and benefit of public-access defibrillation (PAD) in a nation-wide network. We primarily sought to assess survival at 1 month but information about the circumstances of each OHCA is provided as well.

Methods: In this 28-month study, we assessed the use of 807 AEDs in Denmark. When an AED was deployed information about the circumstances of OHCA, the bystander, the AED and the victim’s condition was obtained.

Results: An AED was connected to an OHCA victim prior to the arrival of Emergency Medical Services (EMS) in 48 instances. Ten percent of bystanders were off-duty healthcare professionals. Shockable arrests (N=31, 70%) were significantly more likely to be witnessed (94% vs. 54%) to occur at sports facilities (74% vs. 31%), in relation to exercise (42% vs. 0%), and with improved 30-day survival (69% vs. 15%, p=0.001). Among those present with a shockable rhythm, 20 (65%) had Return of Spontaneous Circulation upon arrival of EMS and 8 (26%) were conscious, which emphasizes the diagnostic value of ECG downloads from AEDs. Survival could be determined in 42 of 44 patients with OHCA of cardiac origin, and was 52% (n=22, 95% CI [38–67]) and the Cerebral Performance Category was 1 (Good Cerebral Performance) in all survivors.

Conclusion: With a 30-day neurologically intact survival of 69% for patients with shockable rhythms, this study provides further evidence of the lifesaving potential of PAD.

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1. Introduction

Sudden out-of-hospital cardiac arrest (OHCA) is a leading cause of premature death in the industrialized world. The major determinants linking a victim with survival are described in the ‘chain of survival’, which compasses early recognition, early cardiopulmonary resuscitation (CPR), early defibrillation, and high-quality post-resuscitation care.1,2

As an integral part of the ‘chain of survival’ the public-access defibrillation (PAD) concept, which encourages laypersons to use Automated External Defibrillators (AEDs) and provide Basic Life Support (BLS) has gained much interest. Several studies have documented high survival rates after OHCA when trained laypersons with a duty to respond used AEDs.3,4 In the prospective, randomized PAD trial, the number of survivors doubled at sites with AEDs and BLS/AED trained lay rescuers, as compared to sites with only BLS trained laypersons and no AEDs.5 This finding was verified in a large population-based cohort study with a population of 21 million in North America6 and a recent nationwide PAD study from Japan showed improved survival as the number of public-access AEDs increased.7

To improve the effectiveness of PAD programmes, the current challenge is to ensure appropriate placement of AEDs and other operational aspects.8 Placement of AEDs at high-risk sites optimizes the life-saving potential of PAD but the high-risk sites may differ between communities.9,9–12 Although deployment of AEDs is increasing7,13 the application rate is poor even when trained bystanders are on scene.5,14 These operational aspects of PAD have been less intensively studied and detailed information about the characteristics of the deployed AEDs, bystander background, and circumstances of the OHCA is scarce. These characteristics could be useful to optimize future organization of PAD programmes.

In this study we describe the use of 807 consecutively placed AEDs in urban, suburban, and rural parts of Denmark. We aimed to examine the use and benefit of PAD in a nation-wide network. We sought to assess survival at 1 month and to provide detailed information about the circumstances, patient characteristics, bystander...
characteristics, and cerebral performance category for patients resuscitated after OHCA.

2. Methods

2.1. Study design and setting

In this 28-month, prospective, observational nation-wide study, we evaluated the use of AEDs. The study period was from September 1st 2009 through December 31st 2011 and took place in Denmark; a Scandinavian country with a population of 5.5 million comprising 43,094 km².

Since 2003, when The National Board of Health legalized the use of AEDs by laypersons, everyone has been able to purchase and use an AED in Denmark. A network has been established by a private foundation Trygfonden (www.trygfonden.dk) where the AEDs can be registered on a voluntary basis (www.hjertestarter.dk) and on December 2011, more than 5000 AEDs were registered on the public accessible webpage. On February 25th 2010, the emergency dispatch centres across the country implemented an IT-solution, enabling them to refer a bystander to the nearest AED, based on the voluntary AED registry. It is unknown but estimated that approximately 15,000 AEDs have been purchased in Denmark.

2.2. Subjects/enrollment

We collected information about the use of all consecutively placed AEDs in a network maintained by the private company Safetygroup (www.safetygroup.dk). We included all episodes where an AED was attached before the arrival of the Emergency Medical Services (EMS). These AEDs were either donated to laypersons by the private foundation Trygfonden (www.trygfonden.dk) or purchased from the company directly. Anyone apart from private companies could apply for an AED. Donation was based upon an evaluation of the area the AED was to cover, the number and age of people present in the area, the accessibility of the AED, and previous cardiac arrests in the area. An equal distribution throughout the country was aimed at, and islands and rural areas with long EMS response times were prioritized.

There was a steering committee in Copenhagen, which included key persons from the Danish Resuscitation Council as advisors. The set-up was tested in Copenhagen and later disseminated to a national level. Representatives from the foundation and the company recruited volunteers and every 6 months, 50 AEDs were donated. If an AED was donated a group of volunteer responders was established and these subjects then participated in a mandatory 4-h European Resuscitation Council (ERC) BLS/AED course. A 2-h retraining course was scheduled to take place every year.

In Denmark there is no legislation regarding the purchase of AEDs. The AED was supplied with only one set of electrodes and whenever an AED was used; the company (Safetygroup) was contacted for the purpose of acquiring new electrodes. This initiated the follow-up procedure.

2.3. Defibrillators

The AED used (HS-1 Philips/Laerdal) delivers a biphasic, truncated exponential defibrillatory waveform at 150 J with each shock.

2.4. Data collection and ethics

When one of the designated AEDs had been used, a company representative went to the location and downloaded the electrocardiography (ECG) data from the AED. Also, contact information about the bystanders was collected. A medical doctor (the first author) then interviewed the bystander and gathered information about the circumstances of the cardiac arrest (witness status, location, and the victim’s level of physical activity), previous BLS/AED training and occupation (healthcare professional or not), distance to the AED, time to AED application/shock and the victim’s condition upon arrival of the EMS.

The data retrieved from the AEDs provided information on initial cardiac rhythm.

The patient was identified through contact to the bystanders, the EMS and the admitting hospital. Informed consent to participate in the study and permission to retrieve the patient’s medical record was obtained from the survivors. The neurological status was determined using the Cerebral Performance Category (CPC) scale: category 1, good cerebral performance; category 2, moderate cerebral disability; category 3, severe cerebral disability; category 4, coma/vegetative state; and category 5, death.

If the patient did not survive approval to retrieve the patient’s medical record was obtained from The National Board of Health (J. nr. 7-604-04-2/134/EHE).

According to Danish law approval from the Ethics Committee was not required, but the processing of personal data was approved by The Danish Data Protection Agency (J. nr. 2007-58-0015/30-0432).

2.5. Definitions

The arrest was presumed to be of cardiac origin if it was not caused by trauma, submersion, asphyxia, exsanguination or other obvious non-cardiac causes.

2.6. End points

The primary endpoint was survival at 1 month.

2.7. Statistics

For statistical analysis the SAS System version 9.1.3 v2 (SAS Institute Inc., Cary, USA) was used.

For continuous data we report median with [25–75% range] and a Mann–Whitney test was used for comparison between the group with an initial shockable rhythm and the group with an initial non-shockable rhythm. Categorical data are reported as absolute number with (proportion) and comparison was done using χ²-test. p-Values < 0.05 were considered statistically significant.

3. Results

A total of 807 AEDs were followed up during the 28-month study period that ended on December 31st 2011, corresponding to 17,562 AED months as the number of AEDs increased throughout the period. The majority of AEDs were donated (68%) and more than half of the AEDs were placed at sports facilities. For further information on location, see Table 1.

We found 48 instances where an AED was connected to an OHCA victim prior to the arrival of EMS. The aetiology of cardiac arrest was non-cardiac in 4 of these cases (1 had epilepsy, 2 had pulmonary embolism, and 1 had penetrating trauma), and the remaining 44 cases were presumed to be cardiac in origin. We report data on the latter group (Fig. 1).

Thirty-one (70%) subjects had ventricular fibrillation, none had ventricular tachycardia, 5 (11%) had pulseless electrical activity and 8 (18%) had asystole. Characteristics of the patients and the cardiac arrests are given in Table 2.
Table 1: Location of the 807 AEDs, number (%).

<table>
<thead>
<tr>
<th>Location of AED</th>
<th>TrygFonden</th>
<th>Safetygroup</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sports facility</td>
<td>353 (64)</td>
<td>73 (29)</td>
<td>426 (53)</td>
</tr>
<tr>
<td>Transportation facility*</td>
<td>19 (3)</td>
<td>1 (0)</td>
<td>20 (2)</td>
</tr>
<tr>
<td>Public</td>
<td>176 (32)</td>
<td>58 (23)</td>
<td>234 (29)</td>
</tr>
<tr>
<td>Attraction (e.g. museum)</td>
<td>46</td>
<td>3</td>
<td>49</td>
</tr>
<tr>
<td>Library</td>
<td>14</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>Citizen association</td>
<td>46</td>
<td>3</td>
<td>49</td>
</tr>
<tr>
<td>Harbour</td>
<td>32</td>
<td>1</td>
<td>33</td>
</tr>
<tr>
<td>School</td>
<td>9</td>
<td>24</td>
<td>33</td>
</tr>
<tr>
<td>Other*</td>
<td>29</td>
<td>27</td>
<td>56</td>
</tr>
<tr>
<td>Residential (institutions)</td>
<td>3 (0)</td>
<td>1 (0)</td>
<td>4 (0)</td>
</tr>
<tr>
<td>Non-public (e.g. companies)</td>
<td>0 (0)</td>
<td>123 (48)</td>
<td>123 (15)</td>
</tr>
<tr>
<td>Total</td>
<td>551 (68)</td>
<td>256 (32)</td>
<td>807 (100)</td>
</tr>
</tbody>
</table>

* Transportation facility refers to airports and major train stations.

Fig. 1. Patient flow. AED, automated external defibrillator; OHCA, out-of-hospital cardiac arrest; PE, pulmonary embolism; VF, ventricular fibrillation; VT, ventricular tachycardia; PEA, pulseless electrical activity; AS, asystole.

3.1. Characteristics of the AED

The bystanders were referred to the AED by the dispatch centres in 5 (13%) of the 40 OHCA cases that occurred after the IT-solution was implemented. One of these patients was alive at 30 days.

Table 2: Characteristics of out-of-hospital cardiac arrest (OHCA), number (%). Mild physical activity is for instance walking. VF/pVT, ventricular fibrillation/ventricular tachycardia; PEA/AS, pulseless electrical activity/asystole.

<table>
<thead>
<tr>
<th>OHCA with initial VF/pVT (N=31)</th>
<th>OHCA with initial PEA/AS (N=13)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years [25–75% range]</td>
<td>68[56–76]</td>
<td>66[54–77]</td>
</tr>
<tr>
<td>Male sex</td>
<td>27(87)</td>
<td>13(100)</td>
</tr>
<tr>
<td>Witnessed</td>
<td>29(94)</td>
<td>7(54)</td>
</tr>
<tr>
<td>Time</td>
<td>11(37)</td>
<td>6(46)</td>
</tr>
<tr>
<td>8 AM to 4 PM</td>
<td>19(63)</td>
<td>6(46)</td>
</tr>
<tr>
<td>4–12 PM</td>
<td>11(37)</td>
<td>6(46)</td>
</tr>
<tr>
<td>12–8 AM</td>
<td>0</td>
<td>1(8)</td>
</tr>
<tr>
<td>Location</td>
<td>23(74)</td>
<td>4(31)</td>
</tr>
<tr>
<td>Sports facility</td>
<td>2(6)</td>
<td>2(15)</td>
</tr>
<tr>
<td>Transportation facility</td>
<td>4(13)</td>
<td>3(23)</td>
</tr>
<tr>
<td>Public, other</td>
<td>1(3)</td>
<td>3(23)</td>
</tr>
<tr>
<td>Residential</td>
<td>1(3)</td>
<td>1(8)</td>
</tr>
<tr>
<td>Non-public (e.g. companies)</td>
<td>1(3)</td>
<td></td>
</tr>
<tr>
<td>Activity</td>
<td>13(42)</td>
<td>0</td>
</tr>
<tr>
<td>During exercise</td>
<td>13(42)</td>
<td>0</td>
</tr>
<tr>
<td>Immediately after exercise</td>
<td>5(16)</td>
<td>1(8)</td>
</tr>
<tr>
<td>Mild physical activity</td>
<td>7(23)</td>
<td>7(54)</td>
</tr>
<tr>
<td>Sedentary activity</td>
<td>6(19)</td>
<td>5(38)</td>
</tr>
</tbody>
</table>

Table 3: Outcome after OHCA in patients treated with AEDs by bystanders.

<table>
<thead>
<tr>
<th>Condition upon arrival of EMS</th>
<th>OHCA with initial VF/VF (N=31)</th>
<th>OHCA with initial PEA/AS (N=13)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROSC, conscious</td>
<td>8 (26)</td>
<td>1 (8)</td>
<td>0.002</td>
</tr>
<tr>
<td>ROSC, non-conscious</td>
<td>12 (39)</td>
<td>1 (8)</td>
<td></td>
</tr>
<tr>
<td>No ROSC</td>
<td>11 (35)</td>
<td>11 (85)</td>
<td></td>
</tr>
<tr>
<td>30-Day survival</td>
<td>20 (69%, 95% CI)</td>
<td>2 (15%, 95% CI)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

For OHCA with initial shockable rhythm (N=31), the median time from collapse to delivery of the first shock was 3 [2–5] min and the median number of shocks was 1 [1–2].

For OHCA with initial non-shockable rhythm (N=13), the median time from collapse to application of the AED was 10 [2–15] min.

The distance from patient to the AED was median 70 [32.5–175] m for the shockable arrests and 77 [30–170] m for the non-shockable arrests, which was not significantly different (p=0.89).

3.2. Characteristics of bystanders who used the AEDs

It was possible to interview 41 of the bystanders to the 44 OHCA. Those unreached were abroad or had changed employment. All the interviews were done by telephone and performed by the first author at a median of 8 [4–30] days after the event.

Among the 41 interviewed, 4 (10%) were off-duty healthcare professionals, including 2 medical doctors, 1 nurse and 1 EMS provider. All but one of the bystanders were trained in BLS/AED, the latest training occurring 9 [6–12] months ago.

3.3. Outcome and in-hospital treatment

Survival data at one month was obtained for 42 of the patients identified. The overall survival among these OHCA victims was 52% (n=22, 95% CI [38–67]) with a significantly higher survival rate among patients with shockable rhythm compared with non-shockable rhythm (69% vs. 15% respectively). All OHCA survivors were interviewed by the first author at a median of 34.5 [21–91] days after the cardiac arrest. The Cerebral Performance Category was 1 (Good Cerebral Performance) in all the subjects (Table 3). One of the OHCA patients with missing survival data had a witnessed VF.
OHCA and the other patient died on the 25th day after the OHCA. However, this information was obtained from the bystanders and could not be verified through official registries, as the patient’s civil registration number could not be obtained.

4. Discussion

With an overall 30-day survival of 52% (95% CI [38–67]) this prospective, observational nation-wide study provides further evidence of the lifesaving potential of public access defibrillation. Among those with an initial shockable rhythm, 69% (95% CI [51–83]) were alive at one month. All survivors were neurologically intact (CPC 1).

OHCA with shockable heart rhythm were more likely to be witnessed, to occur at sports facilities, and in exercise. These characteristics were significantly different from the arrests presenting with an initial non-shockable rhythm, although this must be interpreted cautiously, as the majority (53%) of AEDs were located at sports facilities. The strengths of this study include the comprehensive data collection providing us with very detailed knowledge of the circumstances of each cardiac arrest, from before the victim collapses to the in-hospital treatment. We managed to interview all the survivors, up to 342 days after the OHCA, which provided us with a better estimation of the permanent neurological function than possible in other studies with much shorter follow-up.7,12,13 We have detailed information about the exact location of the AEDs and retrieved recorded ECGs from all AEDs regardless of initial heart rhythm, in contrast to other studies that only report data from shockable arrests.7,12 This provides us with a valuable insight in the circumstances when bystanders decide to take action. The same medical doctor collected all data, ensuring a uniform procedure across different communities. The AEDs were placed nationwide, in urban, suburban and rural areas, making the results more generalizable.

There are several limitations to our study. Firstly, we are unaware if any other cardiac arrests occurred near the AED sites, but without deployment of the AED. Secondly, there could be other contributions to the high survival rate than the use of AEDs, i.e. the quality of BLS performed by the bystanders or EMS response times, which are unknown. Other studies have the same limitation.7,15 Third, although nationwide, we only had information about AEDs that were part of a structured AED programme. It is reasonable to assume that these AEDs are deployed faster and at more healthy persons, since the bystanders were trained and the victims healthy enough to do exercise, as many of the AEDs in this study were located at sports facilities. If the study had included the remaining approximately 4000 registered AEDs in Denmark, the outcome might have been worse, as our results are biased in favour of exercise facilities. Fourth, despite persistent efforts it was not possible to gather complete information on all cases, but it is unlikely that the missing information is biased in any direction.

Nevertheless, a 30-days survival rate of 60% for victims of OHCA with an initial shockable rhythm is a major finding as the general survival rate in Denmark after OHCA is below 10%. Our finding is in accordance with other PAD studies both with and without trained lay rescuers.3,12,15

Linking PAD to the dispatch centres can be an important strategy to improve resuscitation16 but in this study it did not impact on survival as in only 13% of the OHCA the bystanders were referred to the AED by the dispatch centre and all but one of these patients died. Resources should be allocated to investigate how this system can be used more appropriately.

EMS recordings of initial cardiac arrests rhythms have shown a marked decline in the incidence of shockable rhythms. Twenty years ago, shockable rhythms accounted for 70–80% of cardiac arrest rhythms whereas the prevalence today seems to have declined to approximately 25%.17–20 This could jeopardize the concept of AEDs and PAD. However, the high survival rates found in our study probably reflects that when ECG rhythms are downloaded from AEDs in an earlier phase of cardiac arrest, the prevalence of shockable rhythm is high. In our study, the VF incidence was 70%, which is in accordance with the 59–75% found in other studies.6,13,21

We have previously described the value of downloading ECG records from deployed AEDs, also when the initial rhythm was non-shockable.22,23 In this study one ECG download showed a 2nd degree atrio-ventricular block.

In a review of 49 studies, the pooled survival rate to hospital admission was 23.8%.24 In our study, 65% of the patients with an initial shockable rhythm had Return of Spontaneous Circulation (ROSC) at the arrival of EMS. This is very different from other PAD studies with much lower rates of ROSC (between 18%7 and 35%13), and one explanation could be the short interval from collapse to first shock. In our study 26% of those with an initial shockable rhythm were conscious upon EMS arrival. Therefore, it is not surprising that uncertainty can arise whether or not this patient actually had a cardiac arrest. Also in these situations, the downloaded ECG from the AED is valuable and the AED becomes a diagnostic tool.

Among the OHCA with an initial shockable rhythm the median time from collapse to first shock was only 3 [2–5] min, which is in accordance with other studies.7,12,15 Unsurprisingly, for the non-shockable rhythms the mean time from collapse to application of the AED was 10 [2–15] min. This could probably be explained by the fact that fewer OHCA with an initial non-shockable rhythm were witnessed (54% versus 94%). In addition, 23% of non-shockable OHCA occurred in residential areas (versus 3% for the shockable rhythms), thereby increasing the AED retrieval time compared with public arrests. In many cases laypersons brought the AED to a victim’s house from a nearby location. This was not guided by the dispatch centre, but illustrates the impact of AEDs in local communities. It is an important finding, as 60–80% of OHCA occur at home and placement of AEDs in private homes has not showed a survival benefit.1,25

Interestingly, the bystanders were competent at recognizing ‘true’ OHCA, as only 4 out of 48 cases had a non-cardiac aetiology of cardiac arrest, and in at least 3 of the cases, healthcare professionals would also have applied a defibrillator.

The use of AEDs in Denmark is not restricted to trained laypersons, but in our study all but one lay responder was trained. Probably, the trained lay responders recognized OHCA faster than untrained bystanders and training might increase the willingness to initiate bystander CPR. The proportion of healthcare professionals among the lay responders was 10%, which is lower than the 43% and 32%, respectively, reported in other studies.6,12

OHCA with an initial shockable rhythm had a significantly higher survival rate and these OHCA were significantly more likely to occur at sports facilities, as compared to those with an initial non-shockable rhythm. Although this pattern could be related to the fact that many AEDs were in exercise facilities, our results underscores that AEDs should be placed strategically at public places and not at private premises, if the goal is to achieve maximal benefit.

5. Conclusion

In this prospective, observational study of use of 807 publicly available AEDs, we found 48 cases of cardiac arrest where an AED was applied. Survival at one month was 69% for patients with shockable heart rhythm providing further evidence of the lifesaving potential of public access defibrillation. Shockable arrests had a
significantly higher 30-day survival compared with non-shockable arrests.

**Conflicts of interest statement**

Anne Møller Nielsen and Lars Rasmussen have received unrestricted research grants from TrygFonden. TrygFonden has not taken any part in designing the study, analyzing the data or approving the manuscript.

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**References**


