Out-of-hospital cardiac arrest

Probability of bystander defibrillation relative to distance to nearest automated external defibrillator

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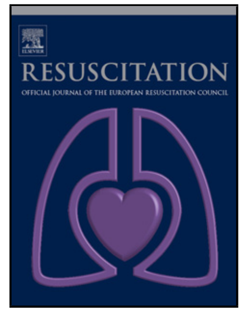

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Out-of-Hospital Cardiac Arrest: Probability of Bystander Defibrillation relative to Distance to Nearest Automated External Defibrillator

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Abstract

Aims Despite wide dissemination of automated external defibrillators (AEDs), bystander defibrillation rates remain low. We aimed to investigate how route distance to the nearest accessible AED was associated with probability of bystander defibrillation in public and residential locations.

Methods We used data from the nationwide Danish Cardiac Arrest Registry and the Danish AED Network to identify out-of-hospital cardiac arrests and route distances to nearest accessible registered AED during 2008–2013. The association between route distance and bystander defibrillation was described using restricted cubic spline logistic regression.

Results We included 6,971 out-of-hospital cardiac arrest cases. The proportion of arrests according to distance in meters (≤100, 101-200, >200) to the nearest accessible AED was: 4.6% (n=320), 5.3% (n=370), and 90.1% (n=6,281), respectively. For cardiac arrests in public locations, the probability of bystander defibrillation at 0, 100 and 200 meters from the nearest AED was 35.7% (95% confidence interval 28.0%-43.5%), 21.3% (95% confidence interval 17.4%-25.2%), and 13.7% (95% confidence interval 10.1%-16.8%), respectively. The corresponding numbers for cardiac arrests in residential locations were 7.0% (95% confidence interval -2.1%-16.1%), 1.5% (95% confidence interval 0.002%-2.8%), and 0.9% (95% confidence interval 0.0005%-1.7%), respectively.

Conclusions In public locations, the probability of bystander defibrillation decreased rapidly within the first 100 meters route distance from cardiac arrest to nearest accessible AED whereas the probability of bystander defibrillation was low for all distances in residential areas.

Keywords: AED, OHCA, distance, bystander defibrillation

Introduction

Automated external defibrillators (AEDs) facilitate early defibrillation and may increase survival chances after out-of-hospital cardiac arrest (OHCA) to more than 50%.[1–3] Consequently, high hopes have been pinned on public AEDs for improving survival rates in OHCA, and several countries have implemented public access defibrillation programs following recommendations from the American Heart Association and the European Resuscitation Council.[4,5] Accordingly, the dissemination of AEDs has rapidly expanded over the last ten years with more than one million AEDs sold in the US alone.[6] However, despite national recommendations and widespread AED deployment, the proportion of OHCAs defibrillated by bystanders before ambulance arrival remain disappointingly low, around 2-4%.[2,3,7,8]

Several barriers to bystander defibrillation using onsite AEDs have been suggested, including distance between AED and victim, location of arrest (public vs. residential location), limited accessibility due to closing times, bystander unawareness of nearby AED, and bystander- and patient-related barriers.[6,9–11] As survival declines from each passing minute, distance to nearest AED is pivotal.[12] Accordingly, previous guidelines from the American Heart Association recommended onsite AEDs to be placed within a short brisk walk (1-1.5 minute) of the victim to "cover" the OHCA.[4] In numerous studies this has been translated to an AED covering an arrest if within a straight line distance of 100 meters (109.4 yards).[9,13,14] However, little is known about the probability of bystander defibrillation relative to distance to a nearby accessible AED in a real-world setting, and it remains to be examined if the distance recommended in guidelines and the geographical optimizing studies is appropriate. Additionally, it remains unknown if the likelihood of AED use according to distance is different in public versus residential settings.

We aimed to assess the association between route distance to nearest accessible onsite AED and probability of bystander defibrillation in public and residential locations.

Methods

Study setting

This nationwide study took place in Denmark with a population of approximately 5.6 million consisting of mixed urban, suburban and rural areas.

Study Patients

OHCA patients were identified from the Danish Cardiac Arrest Registry (http://www.isrctn.com/ISRCTN14261134) during 2008–2013. Only episodes of OHCA where emergency personnel or bystander attempted onsite resuscitation (cardiopulmonary resuscitation or defibrillation) were included, thus excluding subjects where no resuscitative attempts were initiated due to late signs of death. As it is mandatory for the Danish emergency medical services (EMS) to complete a case report for every OHCA they encounter, data are close to complete. Data on exact addresses were subsequently obtained from the EMS providers. Additionally, we included information on relevant OHCA-related characteristics: date, time and location of arrest (public or residential); witnessed status; bystander cardiopulmonary resuscitation (CPR); bystander defibrillation; EMS response time; EMS defibrillation; and survival status at hospital arrival. Thirty-day survival and 1-year survival were obtained from the Danish nationwide Civil Registry.

AED network

The Danish AED Network was established in 2007 and became nationwide in 2010. The AED Network holds information on installation- and registration date, exact location, and opening hours of the location (shop, public building, etc.) of all registered AEDs in Denmark. In 2013, more than 7,500 AEDs were registered in the network corresponding to 1 AED per 750 inhabitants. Registration with the network is voluntary, but strongly encouraged by the National Board of Health and most AED vendors. Since 2010, the AED network and the location of registered AEDs have been linked to the Emergency Dispatch Centres across the country enabling the dispatchers to refer a bystander to a nearby accessible AED. The AED Network has been described in detail previously.[15] An available AED was defined as an AED registered with the AED network and available at the date of OHCA. An accessible AED was defined as an available AED accessible for use (within opening hours) at the time of OHCA. OHCAs with no AED within a 20 km radius accessible for use at time of arrest were excluded.

Geocoding

Exact addresses (cardiac arrests and AEDs) were geocoded according to the European Terrestrial Reference System 1989 (ETRS89) using an open source geographic information system (QGIS) that geocode the addresses (translates an address into X,Y coordinates) via the Danish Addresses Web API (https://dawa.aws.dk/). Subsequently the route distance from each cardiac arrest to the nearest registered AED was calculated using the ArcGIS software[16] and Open Street Map[17]. Thus, the distances reported respond to the shortest route distance between a cardiac arrest location and nearest registered AED calculated using pedestrian routes.

Outcome measure

The primary outcome measure was the probability of bystander defibrillation.

Statistics

Patient characteristics and OHCA characteristics were summarized according to distance (≤100 meters, 101-200 meters, >200 meters) and public/residential location and distance (≤100 meters, >100 meters).

The relationship between the probability of bystander defibrillation and the route distance to the nearest AED was described using restricted cubic spline logistic regression separately for public and residential locations of cardiac arrest. Calendar trends in the proportion of patients with an available AED within 100 meters distance and the proportion with an available AED within 100 meters route distance accessible at time of arrest were analysed using univariate logistic regression.

All hypothesis tests were 2-sided with a level of significance set at 5%.

Data management and statistical analyses were performed using SAS (software version 9.4, SAS institute Inc., NC, USA) and R (version 3.3.2, R Development Core Team).[18]

Ethics

The Danish Data Protection Agency approved this study (Ref.no. 2007-58-0015, local ref.no. GEH-2014-017, I-Suite.nr. 02735). In Denmark, no ethical approval is required for retrospective register-based studies on anonymised data.

Results

All OHCAs from 2008 through 2013 were identified (Figure 1). Distance calculations and assessment of AED accessibility were eligible for 9,678 OHCAs. Information on bystander defibrillation was missing in 300 cases, and 155 cases had missing information on location of arrest. In 2,252 cases, an AED was not accessible at time of OHCA due to restricted opening hours, leaving a final study population of 6,971 cases.

Baseline characteristics according to distance to nearest accessible AED

The key OHCA characteristics and resuscitation status according to distance (≤100, 101-200, >200 meters) to nearest accessible AED are presented in Table 1. The median distance to nearest accessible AED was 800 meters (interquartile range [IQR] 416 – 1580), 73.8% (n=5,142) had arrest in residential locations, and overall 3.7% were defibrillated by a bystander. OHCA cases with shorter distances to nearest accessible AED had more often witnessed arrest and arrest in public location, received more often bystander intervention (CPR and defibrillation), and more cases survived 30 days and 1 year.

Association of distance to AED and probability of bystander defibrillation according to location of arrest

Overall, the probability of bystander defibrillation decreased (31.0%, 12.5% and 5.9%) with increasing route distance (0, 100, 200 meters) to nearest accessible AED.

Figure 2 depicts the probability of bystander defibrillation relative to route distance to the nearest accessible AED stratified on location of arrest. In public locations, the probability of bystander defibrillation at 0, 100 and 200 meters from the nearest AED was 35.7% (95% CI 28.0-43.5), 21.3% (95% CI 17.4-25.2), and13.7% (95% CI 10.1%-16.8%), respectively. The corresponding numbers for OHCAs in residential locations were 7.0% (95% CI -2.1%-

16.1%), 1.5% (95% CI 0.002%-2.8%), and 0.9% (95% CI 0.0005%-1.7%) respectively. In a subgroup analysis on witnessed arrest only, a similar pattern was observed; however, the probability of bystander defibrillation was greater for all route distances between witnessed arrest and nearest AED in public locations as opposed to OHCAs in residential locations, where the probability of defibrillation was negligible for all distances (Supplemental eFigure 1). Notably, a total of 3 patients were bystander defibrillated in residential locations amongst witnessed arrests with less than 200 meters to nearest accessible AED, consequently, these findings are prone to statistical uncertainty. To test the robustness of our results, we analysed the association between the probability of defibrillation and distance to nearest inaccessible AED and found no association.

Association of distance to nearest accessible AED and 30-day survival

The overall probability of 30-day survival was 28.2% (95% CI 22.8-33.5), 22.2% (95% CI 19.3-25.2), and 17.1% (95% CI 14.9-19.2) at route distance 0, 100 and 200 meters from the nearest AED, Figure 3.

Characteristics for patients with an accessible AED within 100 meters of cardiac arrest

Overall, amongst the 320 patients with an accessible AED within 100 meters route distance, 22.8% (n=73) were bystander defibrillated before EMS arrival, Table 2. Of those, 63.2% (n=43) survived the first 30 days compared with 15.4% (n=32) among those not defibrillated by bystanders.

A total of 68.2% (n=218) had an arrest in a public location and 31.8% (n=102) had an arrest in a residential location. Characteristics according to location are presented in Table 3.

Time trends in cardiac arrests with an AED within 100 meters distance and AED accessibility

Throughout the study period a significant increase in the proportion of OHCAs with an AED within 100 meters was observed (1.2% in 2008 vs. 8.5% in 2013, p=0.004), Supplemental eFigure 2. A similar trend was observed in OHCAs with an accessible AED within 100 meters route distance at the time of arrest (1.0% in 2008 to 5.7% in 2013, p=0.03). We tested the influence of time trends in the AED deployment in a subset analysis including only OHCAs from 2011–2013 and got similar results, Supplemental eFigure 3. The proportion with arrest in residential locations increased during the study period from 65.2% to 74.4%, p<0.001, Supplemental eFigure 4.

Discussion

This nationwide study investigating the association between probability of bystander defibrillation and route distance to nearest accessible AED in a real-life setting had three major findings: (1), the probability of bystander defibrillation decreased by more than a third within the first 100 meters route distance to nearest accessible AED in OHCAs in public locations, whereas OHCAs in residential locations had overall low probability of defibrillation; (2) less than 5% of OHCA cases had an accessible AED within 100 meters distance, though the proportion increased during the study period; and (3) less than one fourth of OHCA cases with an accessible AED within 100 meters of distance were defibrillated by a bystander.

Following previous guidelines from the American Heart Association, an AED is considered as providing coverage if within 1 – 1.5 minutes brisk walk from an OHCA, corresponding to approximately 100 – 150 meters (109.4 – 164.0 yards) walking distance.[4] This study revealed that the probability of receiving bystander defibrillation in public locations rapidly declined during the first 100 meters route distance from OHCA to the nearest AED, and that the probability of bystander defibrillation in residential locations was low for all route distances, indicating an overall low use of onsite AEDs in residential locations. An analogous decrease in 30-day survival relative to increasing route distance was observed, which concurs with already established knowledge of early bystander defibrillation improving survival rates from OHCA.[19] Importantly, distances used in this study represents walking route distances based on local infrastructure (roads or pedestrian paths), suggesting that the coverage of an onsite AED might be less than the 100 meters straight line distance used in previous theoretical studies.[9,14] The current guidelines from the American Heart Association and the European Resuscitation Council state no recommendations to density of deployed AEDs in high-risk areas. However, our findings indicate that the coverage area of an onsite public AED might be more limited than previously anticipated, which is important to take into account when strategically placing AEDs and implementing Public Access Defibrillation programs.

Concurrent with previous studies, we observed that the majority of OHCAs with bystander-initiated defibrillation occurred in public locations.[20] As few AEDs are deployed in residential areas, we anticipated that OHCAs in residential locations had longer distances to nearest accessible AED.[21,22] Nonetheless, despite having an accessible AED within 100 meters route distance, very few patients in residential locations were defibrillated (4%). Impediments to bystander defibrillation in residential locations have yet to be identified. We do know, however, that OHCA patients in residential areas are overall frailer, older and with more comorbidity than patients in public locations.[21] Nonetheless, in this study, 18% of

OHCAs in residential areas with an accessible AED within 100 meters distance were subsequently EMS defibrillated, which indicates a potential for bystander defibrillation also in residential settings, and that the reason for low bystander defibrillation rate is not solely related to non-shockable heart rhythm. Bystanders in residential locations tend to be more often alone as compared to bystanders in public locations with published incidences of 56% vs. 18%, respectively.[23] A lone bystander might stay and perform CPR, not prioritizing the retrieval of a nearby AED.[5] Hence, improved guidance to the nearest AED by the emergency medical dispatchers might prove futile for many OHCAs in residential locations. Consequently, other approaches are needed, such as activating first responders. Several studies have reported promising results from experiences with early CPR and defibrillation facilitated by first responder programs where layperson first responders or professional first responders (fire fighters or policemen) are dispatched from the emergency dispatch centre simultaneously with the EMS as part of an organized response.[24–26] Hence, first responders have the potential to enhance the AED coverage area and might be of particularly importance in residential areas where the proportion defibrillated remains poor.[7,26,27]

Altogether, despite having an accessible AED within 100 meters distance, 77% of these OHCAs were not bystander defibrillated. Although our study does not allow us to ascertain, how many cases would have benefitted from bystander defibrillation, we observed that the majority of arrests had bystander-initiated CPR and close to a third was subsequently defibrillated by the EMS, indicating a lifesaving potential, and that the presenting heart rhythm (shockable vs. non-shockable rhythm) could not alone explain the low defibrillation rates. Furthermore, as the proportion with shockable rhythm markedly declines with increasing time to rhythm analysis,[28] the median EMS response time of 12 minutes for

OHCAs not receiving bystander defibrillation in our study implies that an even larger proportion of cases could have presented with a shockable rhythm, had an AED been applied earlier. The reason for the low bystander defibrillation rate despite a nearby accessible AED is probably multifactorial including bystander related impediments and challenges with the integration of the Danish AED Network with the dispatch centres. In particular the emergency medical dispatchers play a key part in the early diagnosis of OHCA, and the subsequent dispatching to the nearest accessible AED, and focus on improved dispatcher guidance to nearest AED might enhance use of on-site AEDs. [23]

Finally, despite the wide dissemination of AEDs in Denmark, only 5% of OHCAs had an accessible AED within 100 meters distance, thus most arrests in Denmark were not covered by an accessible AED. Altogether, improved AED coverage and improved dispatcher guidance hold the potential to augment AED use and ultimately increase survival rates. However, ensuring AED coverage of an entire country is a cumbersome task, hence, strategic AED placement via mathematical optimizing models together with first responder programs and dynamic delivery of AEDs to the OHCA scene could be potential solutions.[14]

Limitations

We only had information on bystander defibrillation, as it is not registered in the Danish Cardiac Arrest Registry if an AED was applied, but no shock was delivered. However, in our data 3.7% received bystander defibrillation, which is in accordance with another Danish study investigating AED application and use in the city centre of Copenhagen only, where 3.8% had an AED applied before ambulance arrival.[29] In addition, not all AEDs in Denmark are registered in the Danish AED Network. However, distances to non-accessible AEDs were not associated with bystander defibrillation rates; hence, unregistered AEDs should have minor influence on our results. Close to a third of the patients in the Danish Cardiac Arrest Registry were excluded due to unknown/unregistered address of cardiac arrest location. Nonetheless, the baseline characteristics of the group with missing addresses mimicked the characteristics of our study cohort (for details see Supplemental eTable 1). Finally, we do not know if the AED was placed in a multi-storey building and on what floor, which would make the AED appear closer to the OHCA than it actually was.

Conclusion

In this nationwide study, the probability of receiving bystander defibrillation in public locations decreased rapidly with increasing route distance during the first 100 meters from OHCA to the nearest accessible AED whereas the probability of bystander defibrillation was low for all distances in residential locations. Several OHCA cases were not defibrillated despite having an available AED within 100 meters route distance accessible at the time of arrest. These findings indicate that the actual AED coverage area is more limited than anticipated in previous guidelines and studies investigating the theoretical AED coverage, and represents central knowledge regarding strategic AED deployment in the future and the development of alternative ways to enhance AED use.

Conflicts of Interest

Dr. Sondergaard reports grants from the Danish foundation TrygFonden and grants from The European Regional Development Fund through the Interreg IV A OKS programme. Dr. Hansen reports grants from The Danish Foundation Trygfonden, grants from The Danish Heart Foundation, and grants from The Laerdal Foundation. Dr. Pallisgaard reports grants

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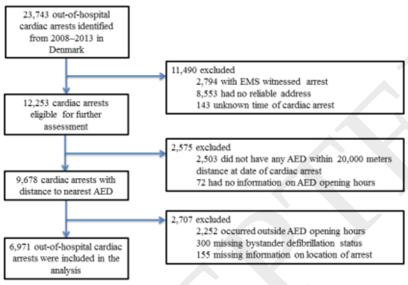
Legends

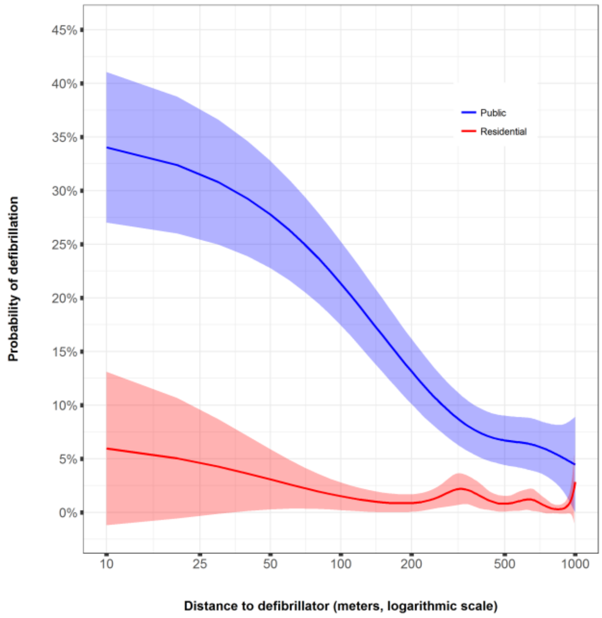
Figure 1 Selection of study population.

AED, automated external defibrillators; EMS, emergency medical services

Figure 2 Probability of defibrillation relative to distance in meters from nearest accessible AED at time of cardiac arrest according to arrest in public or residential location.

Figure 3 Probability of 30-day survival relative to distance to nearest accessible AED at time of cardiac arrest.




45%
40%
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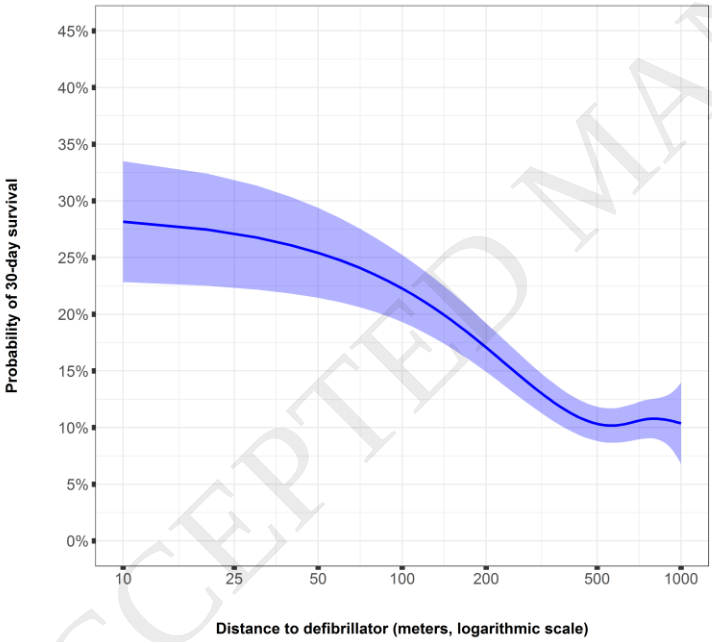
Probability of defibrillation
Public
Residential
10
25
50
100
200
500
1000
Distance to defibrillator (meters, logarithmic scale)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Probability of 30-day survival
10
25
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100
200
500
1000
Distance to defibrillator (meters, logarithmic scale)

Table 1 Cardiac arrest-related characteristics in out-of-hospital cardiac arrest patients according to distance to nearest accessible AED

	Distance from cardiac arrest to nearest AED in meters			**All**	**Missing data**
	≤100	**101-200**	**>200**		
No. (%)	320 (4.6)	370 (5.3)	6281 (90.1)	6971	0
Distance to nearest AED in meter, median (IQR)	39 (11, 72)	156 (130, 178)	896 (522, 1781)	800 (416, 1580)	0
Age, median (IQR)	69 (56, 80)	71 (59, 80)	71 (61, 80)	71 (60, 80)	101
Men, no. (%)	208 (67.3)	226 (62.6)	4022 (65.1)	4456 (65.1)	127
Bystander witnessed, no. (%)	213 (67.0)	230 (62.5)	3264 (52.2)	3707 (53.4)	33
Bystander CPR, no. (%)	231 (72.4)	243 (66.0)	3555 (56.8)	4029 (58.0)	27
Bystander defibrillation, no. (%)	73 (22.8)	30 (8.1)	157 (2.5)	260 (3.7)	0
EMS defibrillation, no. (%)	105 (35.5)	120 (37.0)	1968 (33.0)	2193 (33.3)	394

EMS response time in minutes, median (IQR)	12 (7, 18)	11 (7, 16)	13 (8, 20)	13 (8, 20)	1045
OHCA in private home, no. (%)	102 (31.9)	186 (50.3)	4854 (77.3)	5142 (73.8)	0
Status at hospital arrival, no. (%)					426
CPR stopped	134 (46.5)	163 (50.9)	3464 (58.3)	3761 (57.5)	
CPR to hospital	44 (15.3)	65 (20.3)	1108 (18.7)	1217 (18.6)	
ROSC at hospital	110 (38.2)	92 (28.7)	1365 (23.0)	1567 (23.9)	
Thirty-day survival	79 (26.9)	68 (20.1)	582 (9.8)	729 (11.1)	426
One-year survival	74 (25.2)	64 (18.9)	521 (8.8)	659 (10.1)	426

AED, automated external defibrillator; IQR, interquartile range; CPR, cardiopulmonary resuscitation; ROSC, return of spontaneous circulation

Table 2 Characteristics of out-of-hospital cardiac arrest patients with nearest accessible AED within 100 meters distance according to bystander defibrillation

	Bystander defibrillation	**No bystander defibrillation**	**Missing data**
No. (%)	73 (22.8)	247 (77.2)	
Distance to nearest AED in meters, median (IQR)	21 (8, 53)	46 (12, 77)	0
Men, no. (%)	61 (84.7)	147 (62.0)	11
Age, median (IQR)	66 (56, 76)	71 (55, 80)	8
Bystander witnessed, no. (%)	65 (89.0)	148 (60.4)	2
Bystander CPR, no. (%)	71 (98.6)	160 (64.8)	1
EMS defibrillation, no. (%)	38 (53.5)	67 (29.8)	24
EMS response time in minutes, median (IQR)	12 (8, 17)	12 (7, 18)	65
Arrest in residential location, no. (%)	4 (5.5)	98 (39.7)	0
Thirty-day survival	43 (63.2)	32 (15.4)	44
One-year survival	41 (60.3)	30 (14.4)	44

AED, automated external defibrillator; IQR, interquartile range; CPR, cardiopulmonary resuscitation

Table 3 Characteristics of out-of-hospital cardiac arrest patients according to location of arrest

	≤100 meters to nearest AED		**>100 meters to nearest AED**	
	Residential	**Public**	**Residential**	**Public**
No. (%)	102 (31.8)	218 (68.2)	5040 (75.8)	1611 (24.2)
Distance to nearest AED in meters, median (IQR)	57 (24, 86)	30 (8, 64)	898 (515, 1745)	659 (327, 1350)
Age, median (IQR)	75 (62, 82)	68 (55, 78)	72 (62, 81)	69 (57, 79)
Bystander witnessed, no. (%)	48 (48.0)	165 (75.7)	2447 (48.8)	1047 (65.3)
Bystander CPR, no. (%)	56 (54.9)	175 (80.6)	2646 (52.7)	1152 (72.0)
Bystander defibrillation, no. (%)	4 (3.9)	69 (31.7)	59 (1.2)	128 (7.9)
EMS defibrillation, no. (%)	17 (17.9)	88 (43.8)	1404 (29.1)	684 (46.9)
Thirty-day survival	4 (4.0)	75 (38.7)	344 (7.2)	300 (20.8)
One-year survival	4 (4.0)	70 (36.1)	298 (6.2)	282 (19.5)

AED, automated external defibrillator; IQR, interquartile range; CPR, cardiopulmonary resuscitation