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Clinical paper

Global positioning system alerted volunteer first responders arrive before emergency medical services in more than four out of five emergency calls

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Abstract

Aim: To evaluate response rates for volunteer first responders (VFRs) activated by use of a smartphone GPS-tracking system and to compare response times of VFRs with those of emergency medical services (EMS). Furthermore, to evaluate 30-day-survival after out-of-hospital cardiac arrest (OHCA) on a rural island.

Methods: Since 2012 a GPS-tracking system has been used on a rural island to activate VFRs during all emergency calls requesting an EMS. When activated, three VFRs were recruited and given distinct roles, including collection of the nearest automatic external defibrillator (AED). We retrospectively investigated EMS response data from April 2012 to December 2017. These were matched with VFR response times from the GPS-tracking system. The 30-day survival in OHCA patients was also assessed.

Results: In 2266 of 2662 emergency calls (85%) at least one VFR arrived to the site before EMS. Median response times for VFRs (n = 2662) was 4:46 min:sec (IQR 3:16–6:52) compared with 10:13 min:sec (6:14–13:41) for EMS ($p < 0.0001$). A total of 17 OHCAs took place in public locations and 65 in residential areas. Thirty-day survival in these were 24% and 15%, respectively.

Conclusion: Use of a smartphone GPS-tracking system to dispatch VFRs ensures that in more than four of five cases, a VFR arrives to the site before EMS. Response times for VFRs were also found to be lower than EMS response times. Finally, the 30-day survival of OHCA patients in a rural area, based on these results, surpass our expectations.

Keywords: First responder, Volunteer, Automated external defibrillator, AED, Smartphone, App, Application, Cardiopulmonary resuscitation, Out-of-hospital cardiac arrest, OHCA, Bystander, GPS, Survival

Introduction

Out-of-hospital cardiac arrest (OHCA) is a leading cause of sudden death in industrialized countries.[1] In Denmark, public initiatives have increased awareness and early action during cardiac arrest, which may have contributed to the substantial increase in bystander cardiopulmonary resuscitation (CPR).[2,3] Also, the number of onsite available automated external defibrillators (AEDs) has grown and a national volunteer-based AED-network has been created to increase

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AED usage.[2,4] Still, survival remains low at about 10% after OHCA.[2,5,6] In previous studies, bystander defibrillation before the arrival of the emergency medical service (EMS) has shown to increase survival up to 74%,[7–9] but these studies were performed in selected high-risk public areas, making it difficult to extrapolate to real-life settings. Further, about three-quarters of OHCAs occur in residential areas,[6,10] where CPR performance, defibrillation and survival are markedly lower compared with OHCAs in public areas.[11] Recently, studies have examined the use of GPS or text-message based systems to alert volunteer first responders (VFRs)[12–14] during suspected cardiac arrest. These studies, however, did not measure the number of on-site VFRs, response-times, nor did they demonstrate prognostic effects of the systems used. In 2012, on the island of Langeland, Denmark, a smartphone application was developed, which used global positioning system (GPS) to locate and dispatch VFRs to emergency sites along with standard EMS response. In each emergency call the selected VFRs were given one of three different tasks.

In this study we aim to investigate the response rates and response times for trained VFRs compared to EMS when using a smartphone GPS-tracking system on a rural island. Our secondary aim is to evaluate the 30-day survival after OHCA.

Methods

Settings and study design

This is a retrospective study conducted on the island of Langeland, Denmark. Langeland covers approximately 291 km^2 (about 60 km long and 10 km at the widest point) and has a population of about 12,000 of which one-third live in the city of Rudkøbing. During summer months the population grows substantially.[15] Rudkøbing has an EMS station with an ambulance and a paramedic in a non-transporting EMS vehicle. Langeland has no local hospitals, but is bridge-connected to Funen, where there are two hospitals that both have cardiac care units and one has invasive cardiac facilities.

Emergency medical dispatch centre and AED network

In Denmark, if the emergency medical dispatch centre receives a call and suspects cardiac arrest, the health care professional follows a standardized national protocol to phone-assist the bystander in performing CPR. Also, a two-tiered EMS system is activated following the dispatch of an ambulance and a physician-manned vehicle. On Langeland, a paramedic is always activated when cardiac arrest is suspected.

GPS system and volunteer first responders

The VFRs in this study are citizens that undergo a European Resuscitation Council (ERC)-certified basic life support (BLS) course and a course in emergency first aid. Afterwards they undergo yearly mandatory training to renew their certificates. When the course is completed, the individual VFR downloads a smartphone application (FirstAED), which must be manually activated, when the VFR is available for dispatch.

The GPS-tracking system was introduced in April 2012. On Langeland, the system is activated during all emergency calls, where an EMS is requested. Activation is followed by GPS localization and alert of the nine closest VFRs within 5000 m of the emergency site, who may choose to accept or reject the call. Of all VFRs accepting the call, three are selected based on their location and the placement of the nearest AED. Each of the VFRs is given a distinct role, of which one of the responders is guided to the nearest AED before approaching the emergency site. The AEDs are placed in heated cabinets and when GPS-activated, the cabinet turns on a blue flashlight and a siren alarm. Information about AED location and availability is retrieved through the nationwide AED-network (www.hjertestarter.dk). The other two VFRs must immediately rush to the emergency site and start CPR, assist the EMS staff, comfort bystanders etc. Fig. 1 shows the activation of the GPS-tracking system.

Variables of interest

The main outcome variables of interest are response rates and response times for VFRs vs. EMS. The secondary outcome is 30-day survival after OHCA in residential areas and on public locations.

Covariates of interest are location, bystander CPR, first documented rhythm, VFR arriving with AED before EMS, bystander/VFR/EMS defibrillation and Cerebral Performance Category score.

Study population

The OHCA study population includes EMS-treated OHCAs that occurred on Langeland from 21st of April 2012 until 31th of December 2017. Location of cardiac arrest was defined according to the Utstein-style recommended guidelines.[16]

Patients with obvious late signs of death, non-OHCAs and OHCA due to non-medical causes (suicide, trauma, accidents etc.) were excluded.[16] Also, patients with OHCAs occurring in nursing homes were excluded. Cardiac and non-cardiac causes of cardiac arrest were defined according to the 2015 updated Utstein guidelines.[17]

Data collection

Data was collected following the Utstein-recommendations for reporting resuscitation outcomes.[16] Information about the response times of EMS and VFRs was collected from the emergency medical dispatch centre in the Region of Southern Denmark.

From April 2012 to September 2015 patient data retrieved by EMS personnel was filled out on paper reports, which were systematically screened to identify OHCAs. From September 2015 EMS information was filled out and stored electronically (Elektronisk Patient Journal), and therefore all journals reporting problems involving airways/breathing/circulation were screened along with those reporting cerebral derangement (unconsciousness, epileptic seizures etc.). To cross-check for missing OHCAs, the medical dispatch centre in the Region of Southern Denmark provided a data extraction on all patients that had any information written in the field "Cardiac Arrest". Information about in-hospital treatment and survival was retrieved from hospital records using each patient's unique personal identification number.[18]

Statistics

The categorical variables will be presented as frequencies and percentages. Comparison between categorical groups will be performed using the Pearson's chi-square test or Fisher's exact test, depending on sample size. Continuous variables, e.g. response times, will be visually inspected for normal distribution and displayed using mean (±standard deviations), and in group comparisons Student's t-test or a one-way analysis of variance (ANOVA) will be used, depending on the number of independent groups in the comparison. If more than one VFR arrives at the emergency site, the

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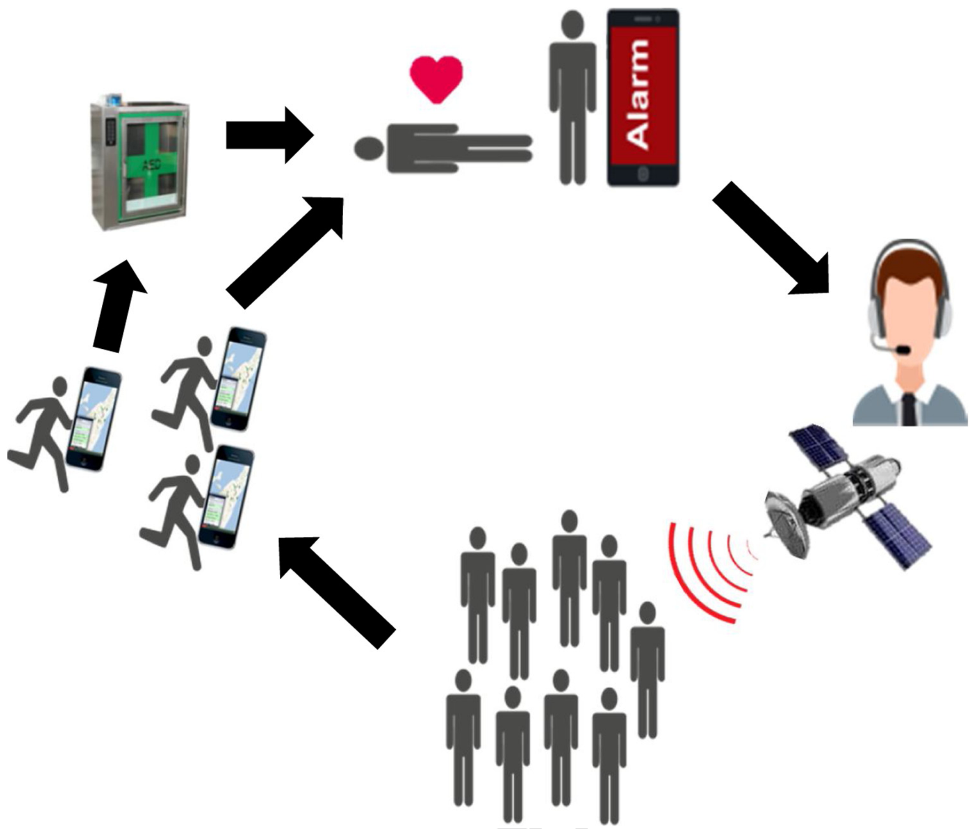

Fig. 1 – Shows how the global positioning system activates nine volunteer first responders (VFRs) and dispatched three VFRs based on their geographical location. The EMS is dispatched simultaneously (not portrayed).

shortest response time will be used. This also applies if more than one EMS arrives to the emergency site. To describe non-normally distributed continuous variables, medians with 25th and 75th percentiles will be presented. To perform group comparisons between non-normally distributed variables, the non-parametric Mann Whitney U-test and Kruskall-Wallis test will be used in cases of two or more group comparisons, respectively. The statistical significance level is 5%. Analysis will be performed by use of STATA version 15 (StataCorp LP, College Station, Texas).

Ethics and data protection

The study was approved by The Danish Data Protection Agency (Journal no. 17/32047) and the Danish Patient Safety Authority under the administration of Danish Health Authority (no. 3-3013-2848/1, ref. LOSC). In Denmark, ethical approval is not necessary for this type of study.

Results

In 2012, 185 citizens of Langeland were registered as VFRs; in 2017 this number had slightly decreased to 170. During the $5^1/_2$-year inclusion period, 96 AEDs were registered on Langeland.[15]

The GPS-tracking system was activated in 2774 emergency calls (Fig. 2). In 101 calls (4%) none of the VFRs responded. In 2662 calls (96%) at least one VFR arrived to the emergency site, and in 2266 of these (85%), the VFR arrived before the EMS. In 1745 of 2662 cases (66%) the VFR brought an AED to the emergency site before EMS arrival (Fig. 2). In nearly two-thirds of the 2662 emergency calls, all three VFRs arrived to the emergency site (n = 1648, 62%) (Supplementary Appendix I).

The median response time for all VFRs (n = 2662) was 4 min and 46 s (Table 1). The response time for VFRs bringing an AED to the emergency site (n = 2380) was 6 min and 21 s. In comparison, the response time for EMS (n = 2763) was 10 min and 13 s, which was significantly higher compared with both VFR groups ($P < 0.0001$) (Table 1).

We identified 243 patients with presumed OHCA (Fig. 3), and further assessment revealed that 112 were true OHCAs. Of these, 65 OHCAs occurred in residential areas (58%) and 17 OHCAs occurred in public areas (15%). Thirty patients were excluded as they were located in nursing homes or had unknown/imprecise location of cardiac arrest (Fig. 3). Table 2 shows the demographic and survival data concerning the 82 patients of relevance. The two groups were comparable in age, sex distribution and cardiac disease. Comorbidity occurred more frequently in patients from residential areas than in those from public areas.

Thirty-day survival in OHCA patients from residential areas was 15% (10 of 65) vs. 24% (4 of 17) in OHCA patients from public areas ($p = 0.47$) (Table 2).

Discussion

In this retrospective study, we found that a smartphone GPS-tracking system that locates and activates VFRs results in a 96% response rate

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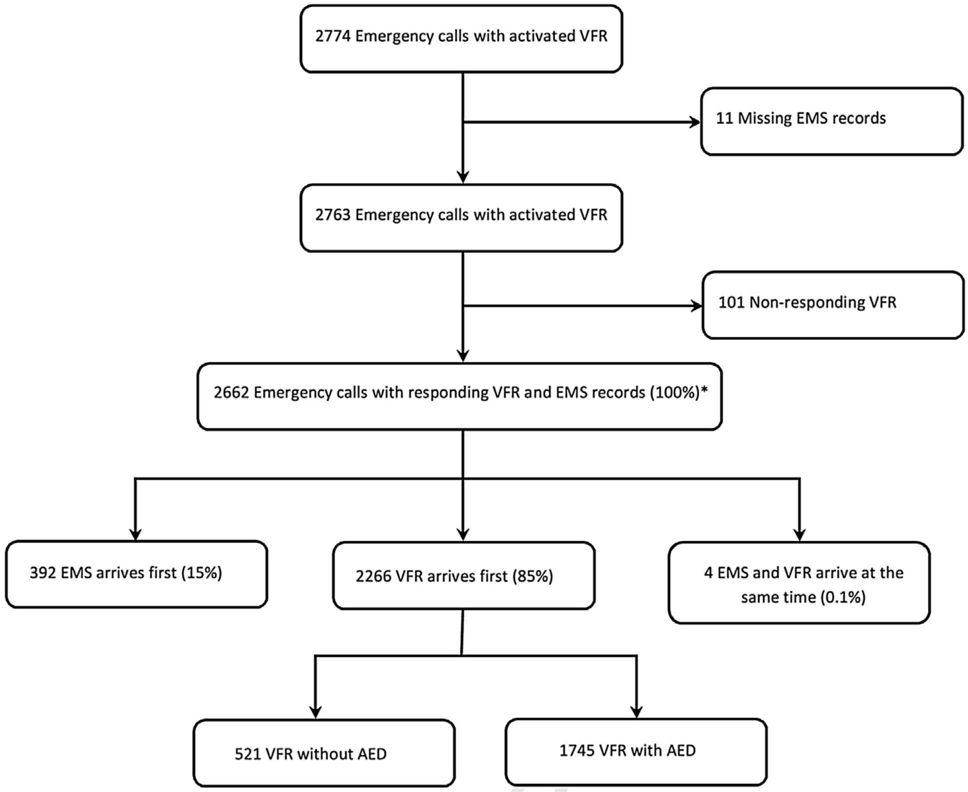

Fig. 2 – Flow-chart showing the number of emergency calls with activation of volunteer first responders (VFR). EMS: Emergency medical service. * 2380 brought an AED.

Table 1 – Response times for the volunteer first responders (VFR) compared with emergency medical service (EMS). AED: automated external defibrillator. IQR: interquartile range.

	Time (min:sec), median (IQR)	P value
EMS (N = 2763)	10:13 (6:14–13:41)	Ref
All VFRs (N = 2662)	4:46 (3:16–6:52)	<0.0001
All VFRs with an AED (N = 2380)	6:21 (4:29–8:49)	<0.0001
VFR with AED on site before EMS (N = 1745)	4:32 (3:07–6:21)	<0.0001

and significantly reduces VFR response times compared to response times for EMS. In more than four of five cases a VFR arrives to the emergency site before the arrival of the EMS. Our observations may suggest that the 30-day survival was higher in both residential and public areas, in comparison with the results reported in earlier OHCA studies.

In Denmark, bystander CPR has increased substantially, probably due to large-scale public initiatives in promoting BLS training and increased awareness concerning early action during cardiac arrest.[2,3] Bystander defibrillation, on the other hand, mainly takes place at public cardiac arrests, and defibrillation in residential areas occurs in less than 5% in most register studies.[2,19,20] Recent studies have evaluated the use of different mobile devices to activate citizens and health professionals and facilitate early BLS in cases of presumed OHCA. In a randomized controlled trial, Ringh et al found that 65% of VFRs within a 500 m diameter accepted the emergency call and 59 % of these arrived before EMS, which lead to a significant increase in bystander CPR.[13] In an observational study, Caputo et al found that using a mobile application to activate VFR increased the response rate up to 70 % compared to 15% using a text-message activating system.[21] In contrast, a survey among VFRs using the PulsePoint system reported that 23% responded to the notification but only 11% arrived at the scene.[22] In our study a 96% response rate was found, and in most of these (85%) the VFR arrived before the EMS. The reasons for the large variation in VFR response rates observed in different studies are unknown. However, we may speculate that different levels of education and training could result in varying commitment among VFRs; as in this study, the first two studies required updated ERC-certification in BLS with annual mandatory certificate renewal,[13,21] which was not the case in the latter study.[22] Also, response rates may vary due to differences in the geographical location and the degree of urbanization in the different studies. Perhaps, in rural areas a stronger feeling of commitment among the local citizens to join a VFR network exists, because AEDs are less common and EMS response times are longer than in densely populated areas.

The number of dispatched VFRs in earlier studies varies markedly. In three different studies,[12–14] VFRs within 500–1000 m of the emergency site were activated. This may be suitable in an urban setting with a high population density. However, it may be difficult to recruit VFRs in a rural area, with longer distances to the nearest

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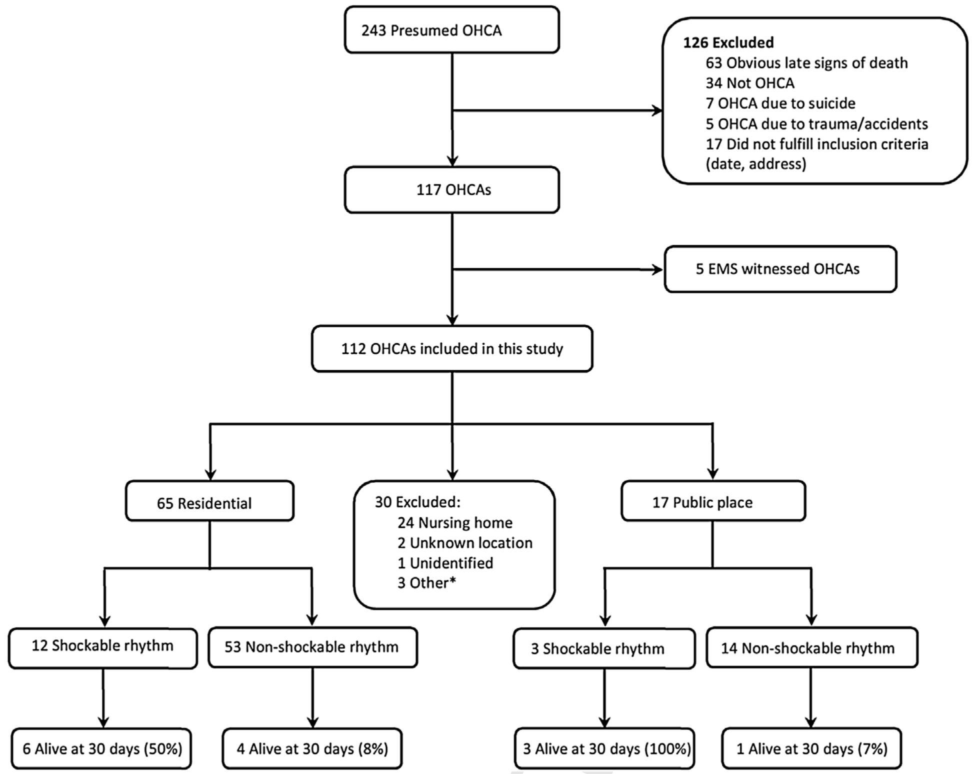

Fig. 3 – Flow-chart showing the inclusion-exclusion process in identifying out-of-hospital cardiac arrest (OHCA).

available EMS, which may also require that VFRs use transport vehicles to reach the emergency site. This issue has been addressed by Auricchio et al, where VFRs covered a median distance of 1196 m to reach the emergency sites.[23] The VFRs travelled with an average speed of 24 km/h, suggesting the usage of motorized vehicles. The study, however, reported a 100% response rate among eligible VFRs, which has been yet unseen. Also, the study could not describe the alert strategy in selecting VFRs to either locate the nearest AED or to reach the site immediately, nor could they describe the number of AEDs arriving to the site before EMS. The island of Langeland consists mainly of rural countryside, and to reach a wider VFR and AED coverage, the smartphone GPS-tracking system in this study used a 5000 m radius. This did not appear to reduce VFR response rates in this study, where at least two of three VFRs responded to the emergency call in the majority of emergency calls (Supplementary Appendix I). Moreover, only three VFRs were dispatched per emergency call, which is a relatively low number compared to other studies,[12–14,24,25] but neither this appeared to affect the response rates among VFRs (Supplementary Appendix I). Perhaps, this is an important consideration in the efforts to optimize the response rate for VFRs. If a high number of VFRs arrive to the emergency site only to find that other VFRs are already present, they may feel demotivated and become less eager to accept future calls. Of course, this is speculative, but should perhaps be a concern when designing future studies in this field.

So far, only one study has compared VFR response times with the conventional EMS response times.[24] Berglund et al used a smartphone application to activate CPR-trained lay volunteers in all cases of suspected OHCA. A significant reduction in response time (6:17 min for first arriving responder versus 9:36 min for EMS) was found. However, the study only covered greater Stockholm and was not active during night hours.[24] This issue is of major importance when evaluating the actual reduction in time to CPR and defibrillation. It is well established that survival after OHCA is extremely time-sensitive, and the minute-to-minute mortality risk until defibrillation can be reduced to 3–4 % per minute with early CPR.[26] In the present study, we demonstrate that the GPS-tracking system has the potential to increase rates of bystander CPR as well as to reduce the time to CPR in OHCA patients, which ultimately may lead to improved survival.

Cardiac arrest in residential areas comprises three-quarters of OHCAs in most studies.[6,10] Yet, survival in these patients remains low compared to cardiac arrest in public areas. The reasons for the discrepancy is multifactorial; cardiac arrest in residential areas are more frequently unwitnessed, have lower rates of bystander CPR, the population is older with more comorbidity and has more often non-shockable rhythm.[2,11] Also, the number of available on-site AEDs is skewed in favour of public locations[2], which further complicate AED use in residential areas. A study by Hansen et al demonstrated a higher frequency of shockable first rhythm from AED data compared with EMS data,[27] perhaps due to shorter time from collapse to rhythm analysis. In the study by Zijlstra et al, a text-message based alert system resulted in a reduction in time to defibrillation in residential areas, compared with defibrillation by conventional EMS personnel.[14] However, the number of VFRs actually reaching the site was unknown and the study did not evaluate the prognostic impact.[14] In 2014, only 0.8% of residential OHCAs in Denmark underwent bystander defibrillation,[10] which, in this study took place in 13% of OHCAs in private homes. Also, we demonstrated an increase in 30-day survival after OHCA in both residential and public areas, with a combined survival of 17% (14 out of 82 patients), which is markedly higher compared to other studies in this

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Table 2 – xxx.

	Residential area (N = 65)	Public area (N = 17)
Age, median (IQR)	70 (63–82)	71 (59–77)
Male sex, no. (%)	46 (71)	13/16 (81)
Cardiac cause, no. (%)	51 (78)	16 (94)
Witnessed, no. (%)	32/64 (50)	11 (65)
Bystander CPR, no. (%)	53 (82)	17 (100)
Shockable first rhythm, no. (%)	11/64 (17)	3 (18)
Defibrillation before EMS, no. (%)	8/62 (13)	4/16 (25)
Defibrillation by EMS, no. (%)	12 (18)	3 (18)
VFR activated, no. (%)	54 (83)	16 (94)
VFR arrives before EMS, no. (%)	43 (80)	14 (88)
VFR with AED arrives before EMS, no. (%)	36 (67)	11 (69)
Response time, min:sec	5:13 (3:44–6:29)	4:31 (2:39–8:29)
Pre-arrest comorbidity, no. (%)		
Ischaemic heart disease	11/59 (19)	1/13 (8)
Diabetes	11/59 (19)	2/13 (15)
Hypertension	29/58 (50)	4/13 (31)
Ejection fraction ≤45%	10/59 (17)	0/12 (0)
Chronic obstructive	22/59 (37)	0/12 (0)
pulmonary		
Disease	3/59 (5)	0/12 (0)
Chronic kidney disease	7/59 (12)	0/12 (0)
Prior stroke	8/57 (14)	1/12 (8)
Psychiatric disease	6/59 (10)	0/12 (0)
Active cancer		
ROSC at hospital arrival, no. (%)	20 (31)	5 (29)
Alive at 30 days, no. (%)	10 (15)	4 (24)
Cerebral Performance Category Score 1–2 at discharge after OHCA, no. (%)	9/10 (90)	4(100)

CPR: cardiopulmonary resuscitation. EMS: emergency medical service. IQR: Interquartile range. ROSC: return of spontaneous circulation. VFR: volunteer first responder.

field.[10,28,29] It remains uncertain whether these findings is a direct effect of the VFR efforts, however, the rapid VFR response rates and response times combined with early AED use may be favourable for opting early BLS and creating better survival outcomes.

Strengths and limitations

A A strength of this study is the use of a well-established national AED-register that provides VFRs with updated information taking into account the specific availability of AEDs in the nearby area.[23] It is also novel for being the first to provide VFRs with distinct roles, which strengthens team structure during emergency calls. Unlike other studies in this field our study is not register-based, and is characterized by the thorough case ascertainment to identify OHCA subjects in the inclusion period. Also, we cross-checked OHCA data by extracting information from the dispatch centre in the Region of Southern Denmark and thereby identified further two missing OHCA subjects. The civil registration system used in Denmark provides a unique opportunity to identify and collect patient data by matching them across different electronic systems, adding even further to data completion in this study.[18] However, the study has several limitations. It is a single-centre study conducted retrospectively with a small number of OHCAs, and the study is not designed to evaluate causality between the smartphone GPS-tracking system used and its impact on survival after cardiac arrest. Also, this study has a $5^{1}/_{2}$-year inclusion period, and we cannot account for an expected time-dependent rise in 30-day survival after cardiac arrest; there may have been additional citizen BLS training programs and other public initiatives, as well as improvements in prehospital and in-hospital advanced treatment that may have influenced the increase in 30-day survival. This remains speculative.

Conclusion

In this retrospective study, we found that the use of a smartphone GPS-tracking system to alert and dispatch trained VFRs during emergency calls results in a high VFR response rate and significantly reduces response times for VFRs compared to EMS response times. In more than four out of five cases, a VFR arrived to the emergency site before EMS. Finally, our results show a trend towards improved 30-day survival in OHCA patients, however; this calls for further causal research in this field.

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Conflicts of interest

The co-investigators and co-authors Finn Lund Henriksen and Henrik Schakow have stock ownership in the GPS-tracking system, FirstAED, which has been used in this study. All other authors have no conflicts of interest to declare.

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We thank the Langeland AED Association and the volunteer first responder corps for contribution in data collection. We also thank the medical staff at the medical coordination centre in the Region of Southern Denmark for the assistance in acquisition of data.

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.2019.12.010.

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