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Clinical paper

Real-life time and distance covered by lay first responders alerted by means of smartphone-application: Implications for early initiation of cardiopulmonary resuscitation and access to automatic external defibrillators

Angelo Auricchio [a,c,*], *Lorenzo Gianquintieri* [c,d], *Roman Burkart* [c], *Claudio Benvenuti* [c], *Sandro Muschietti* [e], *Stefano Peluso* [f,h], *Antonietta Mira* [f,g], *Tiziano Moccetti* [a,c], *Maria Luce Caputo* [a,b]

[a] Cardiocentro Ticino, Lugano, Switzerland
[b] Department of Molecular Medicine, University of Pavia, Coronary Care Unit and Cardiovascular Clinical Research Center, Fondazione IRCCS Policlinico San Matteo, Pavia, Italy
[c] Fondazione Ticino Cuore, Breganzona, Switzerland
[d] Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milan, Italy
[e] Federazione Cantonale Ticinese Servizi Autoambulanze, Lugano, Switzerland
[f] Data Science Lab, Institute of Computational Science, Università della Svizzera Italiana, Lugano, Switzerland
[g] Department of Science and High Technology, Università dell'Insubria, Italy
[h] Department of Statistical Sciences, Università Cattolica del Sacro Cuore, Milan, Italy

Abstract

Aim of the Study: To investigate the distance covered by lay first responders (LFR) alerted for an out-of- hospital cardiac arrest (OHCA), evaluate the time elapsed between mission acceptance and arrival at the OHCA site, as well as the distance between the LFRs to the closest automatic external defibrillator (AED).

Methods: The LFR route, thus time, distance information, and the average speed of each responder were estimated. The same methodology was used to calculate the distance between the closest AED and the LFRs, as well as the distance between the AED and OHCA site.

Results: Between June 1st, 2014 and December 31st, 2017, the LFR network was activated in occasion of 484 suspected OHCAs. 710 LFRs were automatically selected by the application and accepted the mission. On average 1.5 LFRs arrived at the OHCA site. LFRs covered a distance of 1196 m (IQR 596–2314) at a median speed of 6.9 m/s (IQR 4.5–9.8) or 24.8 Km/h. In 4.4% of the cases the speed of the LFRs was compatible with a brisk walk activity (<1.5 m/sec). The total intervention time of an LFR, who first retrieved an AED and then went to the OHCA site, was longer (275 s, IQR: 184 s–414 s) compared to the total intervention time of a LFR (197 s, IQR: 120 s–306 s; $p < 0.001$), who went to the OHCA site directly without retrieving an AED.

Conclusions: The dispatch of LFRs directly to the OHCA site instead of first retrieving the AED, significantly decreases the time to CPR initiation. More studies are needed to assess the prognostic implications on survival and neurological outcome.

Keywords: Out-of-hospital cardiac arrest, Lay responders, AED, CPR

* Corresponding author at: Cardiocentro Ticino, Via Tesserete, 48 6900 Lugano, Switzerland.
E-mail address: angelo.auricchio@cardiocentro.org (A. Auricchio).

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Introduction

Several communities have promoted and implemented dual-dispatching emergency medical service (EMS) systems which allow dispatched first responders to reduce the time to initiate cardiopulmonary resuscitation (CPR) and the possible use of automated external defibrillation in cases of out-of-hospital cardiac arrest (OHCA). Furthermore, there are lay citizens, possibly trained in CPR and/or automatic external defibrillator (AED) use, who are voluntarily part of a rescue network to start CPR before ambulance arrival. There is consistent demonstration that the involvement of lay first responders (LFRs) in resuscitation significantly reduces the time between collapse and initiation of resuscitation manoeuvres, which eventually improves the outcome.[1]

In some countries, LFRs can be alerted and dispatched to the OHCA location by advanced telecommunication technologies, such as by short message service (SMS) texts or a mobile application.[2–5] Compared to SMS text messaging, a mobile application has the further advantage of displaying the position of a registered AED on the screen of smartphones or smartwatches, thus guiding the dispatched LFRs to the closest AED. Most mobile applications activate a global positioning system (GPS) at the time of alert[5,6] and some of them[6] continuously track the geographic position of the LFRs, from the moment of the alert until the target is reached. This tracking function provides an unprecedented opportunity to monitor the actual time needed and the distance covered by the LFRs involved in rescue missions, including the time and distance to reach an AED and/or OHCA victim. This information may become particularly relevant to further improve mobile application algorithms that automatically manage the LFR network and identify the AED location.

We aimed to investigate the distance covered by LFRs alerted for an OHCA, assess the time elapsed between mission acceptance and arrival at the OHCA site, as well as the distance between LFRs and the closest AED.

Methods

Population and geographic context

The Canton of Ticino region counts a population of 354′375 inhabitants (census year: 2016) distributed in a few densely populated urban areas, and a large number of unequally distributed rural areas within the territory, which enclose a surface of over 2,800 km^2 in the Southern part of Switzerland, made up of mountains, valleys, and lakes.

The EMS system and LFR alerts

Our EMS system and LFR management system has been presented in previous publications.[6,7] In brief, a single dispatching center serves the entire Canton of Ticino and can be reached by dialling a national emergency telephone number, 1-4-4. The dispatching center manages the 7 regional EMSs. When a cardiac arrest is suspected, assisted triage and life support are dispatched and medical assistance is initiated until the arrival in loco of an ambulance. The EMS dispatchers send an ambulance and, in parallel, alerts the professional first responders: i.e. police officers and fire brigade, all trained in Basic Life Support-Defibrillation (BLS-D) and equipped with AEDs. If conditions are regarded as safe, LFRs are also notified by means of the smartphone application. LFRs are civilian volunteers, who may well be off-duty healthcare providers (i.e. physicians, nurses, CPR course graduates), trained in BLS/AED use in compliance with the recommendations of the European Resuscitation Council.[8]

Management of LFR networks by means of mobile application-based alert systems

Our mobile application was previously reported by Caputo et al.[6] Once the alert is launched by the EMS dispatcher, all the LFRs who have downloaded the mobile APP on their smartphone receive the alert notification. The available LFRs press the "I am available" button; from that moment onwards, the LFRs are geo-localized by the mobile application, which also supplies the estimated time needed for each rescuer to arrive on scene (based upon walking pace), and the estimated ambulance arrival time. At this point, the system automatically excludes those responders whose estimated arrival on scene is after the estimated ambulance arrival time. Contrarily, if the estimated time needed by the LFRs to be on scene is shorter than the time needed by the ambulance to arrive on scene, the application calculates the shortest route to reach the OHCA victim and shows it on the screen. Furthermore, the nearby registered AEDs are flagged on the map in order to facilitate their retrieval. The mobile APP continuously tracks the LFRs' position for the whole duration of their mission. The current version of the application prioritizes the LFRs to deliver CPR rather than the AED retrieval; however each LFR may discretionally choose to retrieve an AED.

On June 1st 2014, a mobile application-based alert system was launched. By December 31st, 2017, 3400 resident people had completed a Basic Life Support-Defibrillation (BLS-D) course, and joined the LFR network; at present the group counts 2712 laypersons and 688 off-duty physicians, nurses, or CPR course trainers.

Assessment of the distance to the OHCA and to the AED

The application automatically records and stores the GPS coordinates of the LFRs who press the "I am available" button in a dedicated database. Both the route suggested by the application and the route actually taken by the LFRs, as well as the time elapsed between the mission acceptance and the arrival on scene are also automatically stored for subsequent quality control, analysis and scientific purposes. By combining the information concerning time and distance, the mean velocity of each responder is estimated.

As the LFRs did not always opt to retrieve the AED, the distance between the LFRs and the closest AED as well as the distance between the AED and the OHCA site, were systematically assessed, considering the realistic path to be along roads by using OpenStreetMap roads network shapefile, processed with SQL functions from PgRouting, an extension package for OsGeo SQL server.

The AED geolocation and database

The Fondazione Ticino Cuore owns, registers and maintains every AED installed within the Canton of Ticino (Switzerland). The Fondazione Ticino Cuore supplies AEDs to those institutions, corporations and/or individuals seeking AED installation. Each AED is geolocated; its exact position within a building (i.e. floor, room, etc.), and its availability (public or private AED, availability: 24H/7D, 365 days a year) are on record.

Data collection

The Ticino Registry of Cardiac Arrests (TIRECA) is an Utstein-style registry[7] launched in 2002. It collects information regarding each OHCA occurring within the Canton of Ticino.

Study design

This is a prospective observational study including all OHCAs, which occurred between June 1st 2014 and December 31st 2017 in the Canton of Ticino (Switzerland), in which the LFR network was alerted by means of mobile application. The OHCAs in which the LFR network was not activated were excluded from further analysis. Reasons for not activating the LFR network were: 1) CPR already initiated by a bystander certified in BLS; 2) ambulance arrival time estimated to be shorter than the first responders'; 3) "do not resuscitate" status or evident signs of prolonged death, and/or 4) conditions of the intervention considered unsafe.

Statistical analysis

Data are described as median (25th–75th percentile) for continuous variables, and counts and percent if categorical variables. Stata14.2 (StataCorp, College Station, TX, USA) was used for computation.

Results

Between June 1st, 2014 and December 31st, 2017, 1331 suspected OHCAs occurred in the Canton of Ticino, 1130 of which (85%) were subsequently confirmed to be OHCAs. The demographic characteristics of patients with a confirmed OHCA diagnosis are shown in Table 1. The majority of OHCAs were witnessed, occurred at home and involved elderly males with asystole or pulseless activity (Table 1).

Table 1 – Demographic characteristics of patients with confirmed out-of-hospital cardiac arrest.

Male gender, n (%)	757 (67)
Age, median (IQR)	71 (65–78)
Etiology, n (%)	
Cardiac	847 (75)
Trauma	34 (3)
Respiratory	113 (10)
Intoxication	79 (7)
Other/unknown	57 (5)
Witness, n (%)	
None	350 (31)
Lay people	531 (47)
Professionals	249 (22)
Location, n (%)	
At home	734 (65)
Public place	396 (35)
Rhythm, N (%)	
Shockable	260 (23)
Asystole	452 (40)
Pulseless activity	362 (32)
Others	56 (5)
Bystander BLS, N (%)	791 (70)
Time from call to EMS dispatcher reply (sec)	6 (3–9)
Time from call to ambulance alert / LFR activation (sec)	88 (80–95)
Time to EMS arrival, min (IQR)	10.1 (7.6–13.5)

BLS: basic life support; EMS: emergency medical service.

The LFR network

The LFR network was activated in the event of 484 suspected OHCAs (36%). Among those, 201 events were subsequently re-classified as non−OHCAs, 222 events as OHCAs of cardiac origin and 61 as OHCAs of non-cardiac origin (Fig. 1). 710 LFRs were automatically selected by the application and accepted the mission; 287 LFRs intervened on victims who did not suffer an OHCA (as confirmed by the rescue team), 337 LFRs intervened on OHCAs of cardiac origin and finally, 86 LFRs assisted in OHCAs of non-cardiac origin. On average 1.5 LFRs arrived at the OHCA site. All activated LFRs successfully arrived on the OHCA scene.

Distance and time covered by laypersons to reach the OHCA site

Fig. 2 shows the distribution of the effective time, the distance and the speed of all 710 LFRs arriving at the OHCA site. LFRs covered a distance of 1196 m (IQR 596–2314) with a median velocity of 6.9 m/s (IQR 4.5–9.8) or 24.8 Km/h. The median elapsed time was 191 s (IQR 116–299). In 4.4% of the cases the speed of the LFRs was compatible with a brisk walk activity ($<$1.5 m/sec). However, in the vast majority of cases (85%), the speed varied up to 12 m/sec or approximately 40 Km/h, i.e. the speed of a vehicle travelling within the most usual speed limits (30 Km/h to 50 Km/h) in residential areas.

Time and distance for a lay first responder to retrieve an AED

On December 31st 2017, there were 1216 geolocated AEDs in Canton Ticino, which corresponds to an AED density of approximately 3.4 AEDs per 1000 inhabitants. The median distance between the OHCA and the closest AED (only considering real street paths, and the devices which were accessible at the time of the OHCAs) amounted to 1598 m (563 m– 2260 m). The median distance between the LFRs and the closest AED amounted to 416 m (214 m– 553 m). By using the speed of each LFR, it was estimated that the LFRs engaged in the mission would have reached the closest AED after an average time of 58 s (IQR 30–105 s). The total intervention time of LFRs (275 s, IQR: 184 s–414 s), who first retrieved an AED and then went to the OHCA site, was significantly longer compared to the total intervention time of LFRs (197 s, IQR: 120 s–306 s; $p < 0.001$, Fig. 3), who went directly to the OHCA site. When comparing the intervention time of LFRs with AED retrieval to the time of LFRs without AED retrieval (Fig. 3), the median intervention time difference between the two scenarios was 555 s (IQR: 94 s–1230 s) in case a LFR walked (speed $\leq$1.5 m/sec) and 97 s (IQR: 51 s–697 s, $p < 0.001$) in case a LFR who had a speed of $>$1.5 m/sec.

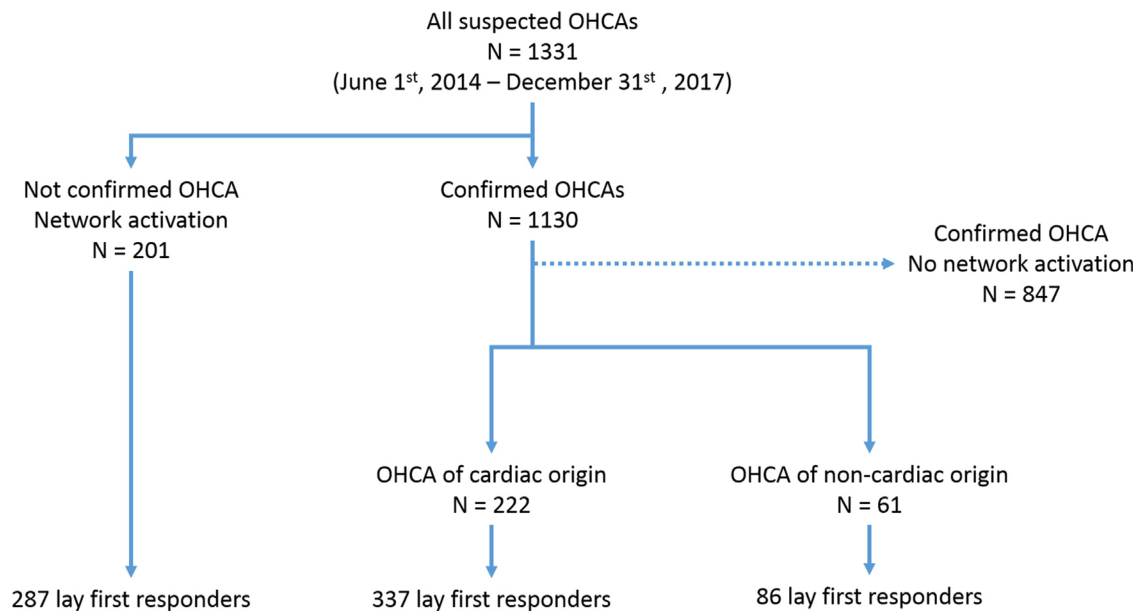

Fig. 1 – Flowchart of patients' inclusion.

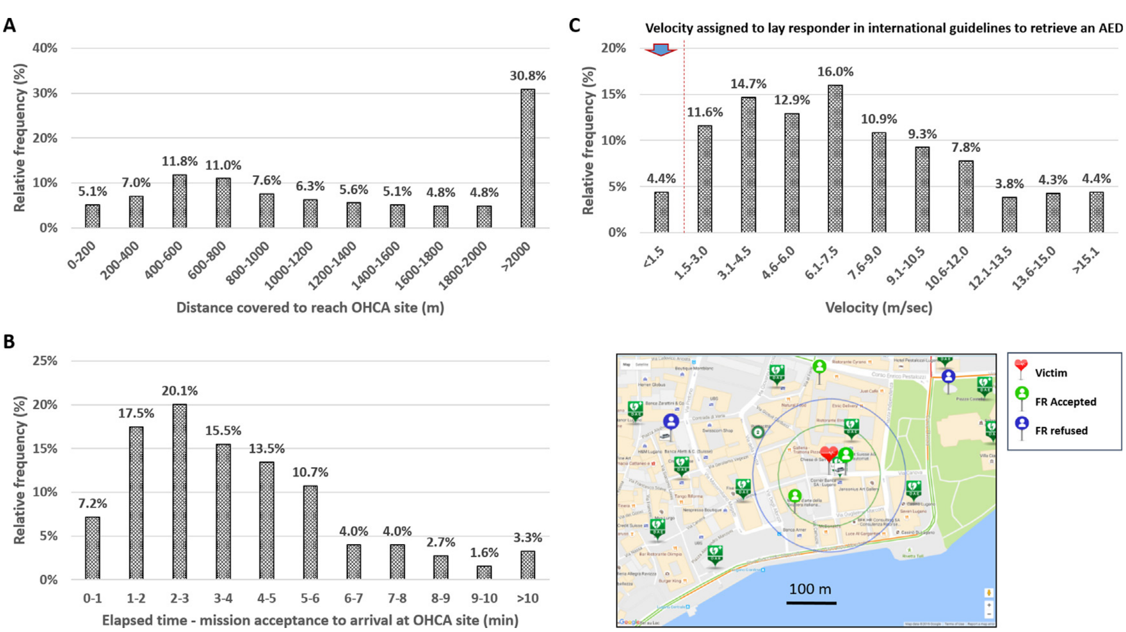

Fig. 2 – Distance covered by lay first responder to reach OHCA site (Panel A), their elapsed time from mission acceptance to arrival at OHCA site (Panel B) and velocity (Panel C) by 710 LFRs. Panel D shows a map with a flagged OHCA site occurred at a residential area, the circular radial area (100 m and 150 m), the relative position of LFRs who were automatically selected (green symbol) or excluded (blue symbol) by the mobile application and the position of the automatic external defibrillator (AED). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

Discussion

To the best of our knowledge, this is the first study to quantitatively assess the use of smartphones and GPS technologies to notify volunteers of nearby OHCAs. Our study included a broad spectrum of emergency situations (confirmed and non-confirmed OHCAs, and OHCAs of cardiac and non-cardiac origin) in which the LFR network was activated for OHCAs occurring either in public locations and/or at home, and over a vast territory. Within the context of our emergency medical system, which includes an ambulance system, a professional first responder and a LFR network, we noticed that dispatching LFRs directly to the OHCA site instead of directing them to the AED site first and only subsequently to the OHCA location, significantly shortens the

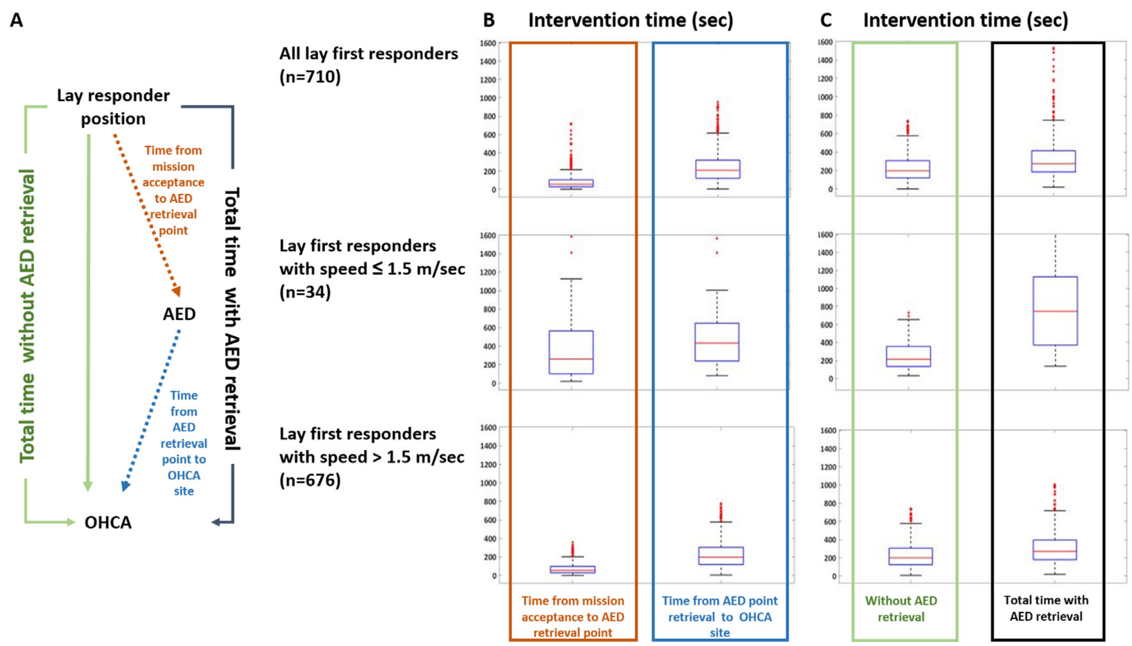

Fig. 3 – Intervention times according to retrieval. Panel A is a schematic representation of possible scenarios. The black arrow indicate the path followed when an AED was retrieved; the green arrow indicates the path followed when no AED was retrieved. Panel B shows the intervention times according to time to mission acceptance to AED retrieval point (red box), the time from AED retrieval point to OHCA site (blue), according to the velocity of the LFRs. Panel C shows the intervention times according to no AED retrieval (green box) or when AED was retrieved (black box), according to the velocity of the LFRs. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

time of CPR initiation. A shorter CPR initiation time and AED use has been shown to improve survival time and neurological outcome,[9,10] especially from public location cardiac arrest.[11,12] The American Heart Association (AHA) guidelines[13] and the ILCOR recommendations[8] for AED placement state that it is reasonable to consider sites where OHCAs are expected to occur once every 2nd to 5th years as well as in public locations where there is a relatively high likelihood of witnessed cardiac arrests. Furthermore, they suggest locating an AED at distances which can be covered on foot in 1.5 min by any layperson. This distance amounts to approximately 100 m.[14,15] Moreover, more recently, it was reported that the likelihood of bystander defibrillation is higher when the closest AED is within 100 m[16] and that the 30-day survival rate may be significantly impacted by the accessibility or non-accessibility of an AED.[17]

Consistent with literature, our study shows that about three-quarters of all OHCAs occurred at home, where on-site AEDs are rarely available.[11,18] In this challenging rescue scenario, it is unknown whether the AED retrieval area can be equally large as those for public locations or whether different ranges of AED retrieval areas should be used. Furthermore, there is a lack of knowledge on the response time of LFRs, their distance from the OHCA site, the usual speed at which they run and, most importantly, their relative distance from an AED and the distance between the AED and the OHCA site. Our data indicate that, in the vast majority of cases, LFRs were significantly distant from the OHCA site – on average 1′500 m. LFRs can only cover this distance by using a private vehicle so as to arrive at the OHCA site within a few minutes. We observed an average speed of 40 Km/h, which is within the range of the usual speed limits (30 Km/h to 50 Km/h) in residential areas. Therefore, our findings may have important clinical and practical implications on the design of automatic LFR management algorithms as well as in mathematical optimization models used for strategic AED placement.

As reported in literature, the likelihood of survival decreases approximately by 10% for every minute of cardiac arrest without intervention.[19] According to this observation, the clinical scenario in which the priority is given to the AED retrieval instead to dispatching LFRs straight to the OHCA site, may lead to a median delay of 78 s in time to reach the OHCA victim, with a corresponding reduction of the chances of survival between 10% and 15%. Although this finding was interpreted cautiously, the strategy of sending LFRs to retrieve an AED first, instead of immediately directing them to the OHCA site, might potentially reduce the contribution of LFRs in early initiation of CPR. On the other hand, this observation is consistent with a recent view of the COSTA (Copenhagen, Oslo, Stockholm, and Amsterdam) study group.[20] In the presence of a 3-tier EMS made up of an LFR network, professional first responders and ambulances, the LFRs shall be immediately directed toward the OHCA site, even more so if the OHCA occurs in residential or rural areas, because the dispatched professional first responders will provide an AED shortly after. Because the vast majority of our LFRs uses a vehicle to reach the OHCA site, one may consider providing each certified LFR with a dimensionally smaller AED than current AEDs, which can be carried on a bicycle, motorcycle or private car. An alternative solution may be the creation of a parallel mobile network of LFRs who deliver an AED, or drone-delivered AEDs when conditions allow it. In case the LFR network is automatically managed by a mobile application-based alert system, priority shall be given to CPR performance whereas the subsequently selected LFRs shall be directed to retrieve the AED.

Due to the lack of published benchmarking data, we are unable to assess the performance of our LFR network. Considering that in about 50% of OHCAs CPR was started within 3 min from the mission acceptance by the LFRs,[6] we expect a survival rate of at least 35% to 40% in case of LFR-intervention. This figure is consistent with a previous report from our group which showed a survival rate in bystander-witnessed OHCAs with VF (Utstein definition) of approximately 55%.[7]

We[6] and other groups[5] have recently reported about the management of LFRs by use of a mobile-phone positioning system to dispatch lay volunteers who were trained in CPR to a patient nearby with out-of-hospital cardiac arrest. A significant increase in rates of bystander-initiated CPR among persons with OHCA was observed by Ringh et al in the city of Stockholm[5] and by Caputo et al in the Canton of Ticino.[6] Our group also showed that a mobile application increases survival rates in both shockable and non-shockable OHCAs.[6]

Limitations

Our database does not record the vehicle used by the LFRs to reach the OHCA site, which however, we do not consider of critical importance. The mobile application we are using is unable to detect whether the LFRs carry and use a private AED; however, this was not the case with any of our LFRs.

Conclusions

Dispatching LFRs directly to the OHCA site instead of directing them to AED site first and only subsequently to the OHCA location, significantly shortens the time of CPR initiation. A shorter CPR initiation time may improve survival time and neurological outcome. Therefore, our findings may have important clinical and practical implications on the design of automatic LFR management algorithms as well as in mathematical optimization models used for strategic AED placement.

Conflicts of interest

None.

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