Clinical paper

Local lay rescuers with AEDs, alerted by text messages, contribute to early defibrillation in a Dutch out-of-hospital cardiac arrest dispatch system[☆]

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ABSTRACT

Aim: Public access defibrillation rarely reaches out-of-hospital cardiac arrest (OHCA) patients in residential areas. We developed a text message (TM) alert system, dispatching local lay rescuers (TM-responders). We analyzed the functioning of this system, focusing on response times and early defibrillation in relation to other responders.

Methods: In July 2013, 14 112 TM-responders and 1550 automated external defibrillators (AEDs) were registered in a database residing with the dispatch center of two regions of the Netherlands. TM-responders living <1000 m radius of the patient received a TM to go to the patient directly, or were directed to retrieve an AED first. We analyzed 1536 OHCA patients where a defibrillator was connected from February 2010 until July 2013. Electrocardiograms from all defibrillators were analyzed for connection and defibrillation time.

Results: Of all OHCAs, the dispatcher activated the TM-alert system 893 times (58.1%). In 850 cases ≥1 TM-responder received a TM-alert and in 738 cases ≥1 AED was available. A TM-responder AED was connected in 184 of all OHCAs (12.0%), corresponding with 23.1% of all connected AEDs. Of all used TM-responder AEDs, 87.5% were used in residential areas, compared to 71.6% of all other defibrillators. TM-responders with AEDs defibrillated mean 2:39 (min:sec) earlier compared to emergency medical services (median interval 8:00 [25–75th percentile, 6:35–9:49] vs. 10:39 [25–75th percentile, 8:18–13:23], P < 0.001). Of all shocking TM-responder AEDs, 10.5% delivered a shock ≤6 min after call.

Conclusion: A TM-alert system that includes local lay rescuers and AEDs contributes to earlier defibrillation in OHCA, particularly in residential areas.

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1. Introduction

Early defibrillation may be the most important determinant of survival of out-of-hospital cardiac arrest (OHCA). Time to first shock provided by an emergency medical service (EMS) defibrillator is eleven to twelve minutes, resulting in low survival.[1,2] To decrease this delay, public access defibrillation programs with on-site automated external defibrillators (AEDs) have been implemented, directed at densely populated and high-risk sites.[3–7] These AEDs can be used by people who are in close proximity of the cardiac arrest and can most effectively decrease time to first shock and thereby increase survival.[1,4] In some countries (e.g. the Netherlands), first responders (e.g. policemen) with AEDs are also dispatched to a suspected cardiac arrest as part of an organized EMS response. They are dispatched to both public and non-public sites, but can decrease time to first shock much less than on-site AEDs. Consequently, they are not able to increase survival to the extent that can be achieved by on-site AED use.[2,8,9]

About three-quarters of all cardiac arrests occur in non-public places, like residential areas, where on-site AEDs are rarely available.[2,6,7,10,11] Patients in non-public places are therefore primarily assisted by dispatched first responders and EMS. To benefit

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optimally from AEDs, residential areas are in need of another type of responder. Such a responder needs to be closer to the cardiac arrest patient than first responders and/or EMS, and must be alerted to take action.

The Dutch Heart Foundation has set a target for action to achieve early defibrillation. It has formulated the concept of "6-minute zones": regions where the emergency response is organized to achieve defibrillation for OHCA within 6 min after emergency call, irrespective of the patients' location. A text message (TM)-alert system, which focuses on OHCAs in residential areas, has therefore been implemented by regional dispatch centers. This system alerts local lay rescuers to perform CPR or directs them to a nearby AED first. In this study we analyzed the functioning of this system with the focus on response times and early defibrillation in relation to other dispatched and on-site responders.

2. Methods

2.1. Settings

In the Netherlands, when a cardiac arrest is suspected, the dispatcher sends two ambulances from a single tier equipped with a defibrillator and first responders (e.g. policemen) with an AED. These first responders are dispatched as part of the organized response but are considered lay rescuers; their training includes the standard ERC basic life support (BLS)/AED course for lay rescuers and they only perform tasks according to this course.

The current study is part of the AmsteRdam REsuscitation STudies (ARREST), an ongoing prospective registry of all OHCAs in the Dutch province of North-Holland, which since 2010 also includes the region Twente. Data are collected according to the Utstein recommendations.[12] The Medical Ethics Review Board of the Academic Medical Center in Amsterdam approved the study and gave a waiver for the requirement of informed consent. Details of the data collection in the ARREST study are described elsewhere.[2]

2.2. Text message responders

Text message (TM)-responders are local lay rescuers who followed a standard ERC BLS/AED course and are recruited by various (local) advertisements and campaigns. Registration takes place via an online database in which they can enter their contact information (including mobile phone number) and specifications of their BLS certificate (number and expiration date). They can enter multiple addresses where they are available at specific times per day of the week. Registrations need to be approved before they are allowed to participate. Yearly retraining is required and is reinforced by removing TM-responders who fail to follow a retraining course after two e-mail reminders. TM-responders are not required to have medical expertise.

2.3. AEDs in TM-alert system

Any individual or organization that owns one or more AEDs can register them in the TM-alert database of AEDs. About 40% of the AEDs are acquired through the municipality and are placed in strategically situated places, where people can easily recognize them. Other AEDs are purchased on initiatives of apartment residents, or owned by communities or companies that make them available in residential areas and public places. Recruitment also takes place through advertisements and campaigns. In addition, some AED manufacturers refer to the system on their websites. The AED owner is responsible for maintenance and replacement of disposables, as needed after use or expiration date. The owner decides whether the AED is available 24 h per day or, for example, only during opening hours of a shop or office. If the documented expiration date of disposables is imminent, owners are contacted to maintain the AED. AEDs are removed from the registry if owners fail to update AED information.

2.4. TM-alert system

TM-responders are dispatched in the event of a suspected cardiac arrest according to regional dispatch guidelines. They can be directed to the site of cardiac arrest, or are directed to collect a nearby AED first. The TM-alert system consists of the described databases of TM-responders and available AEDs, and a software package. The dispatcher manually activates the alert process. The software then automatically accesses the TM-responder and AED databases, identifies nearby available TM-responders and AEDs, and sends text messages to selected TM-responders. Reasons for not dispatching could be: no complete address known at moment of dispatch, an evidently non-cardiac cause, patient aged below eight years, ambulance or first responder nearby, or if an AED is already present.

Fig. 1 illustrates the functioning of the TM-alert system. Initially, all registered TM-responders located <1000 m radius were alerted. Since November 2012, a maximum of 30 TM-responders are alerted. In order to alert the closest TM-responders, the radius of the circle around the patient has been made flexible, starting immediately around the patient but with a maximum of 1000 m. Of all TM-responders, one-third is directed to the patient immediately and two-third (closest to available AEDs) is instructed to retrieve the AED first. The procedure from the decision to alert TM-responders to completion of all TM-alerts, is fully automatic and takes a few seconds.

2.5. Study design

The two regions involved in this study are North-Holland North and Twente. These regions have a comparable number of inhabitants: 645 421 and 626 726, respectively. Both regions have a mix of small to mid-size cities and small villages, and an inhabited surface area of 1420 and 1489 km^2, respectively.

This is a prospective observational study in those municipalities in which the TM-alert system was implemented, in the period of February 2010 until July 2013. From the beginning of the study period, the system was already implemented in full within the region Twente (already operational since 2008). Within the region North-Holland North, the system was incrementally rolled out to the 26 municipalities with complete coverage from March 2013. On July 31st 2013, a total of 695 and 855 AEDs, and 5059 and 9053 TM-responders were registered in the TM-alert system in North-Holland North and Twente, respectively.

The current study included all persons with an OHCA, regardless of cause, in whom EMS personnel started or continued a resuscitation attempt. We excluded EMS-witnessed cardiac arrests and aborted resuscitation efforts in individuals with a "do not resuscitate" status or with signs of prolonged death.

2.6. Data collection

EMS personnel routinely reported whether an AED was connected and if so, by which type of responder. All first responders and AED owners in the TM-alert system contacted the study center if their AED was used. On-site AEDs were traced by contacting the site of cardiac arrest. All continuous recordings of EMS defibrillators were sent to the study center by Internet and automatically corrected for clock drift. Study personnel retrieved the electrocardiograms (ECGs) from all AEDs and stored and analyzed them with dedicated software. Clock drift from all AEDs was also corrected to standardized times for each ECG at the moment of data
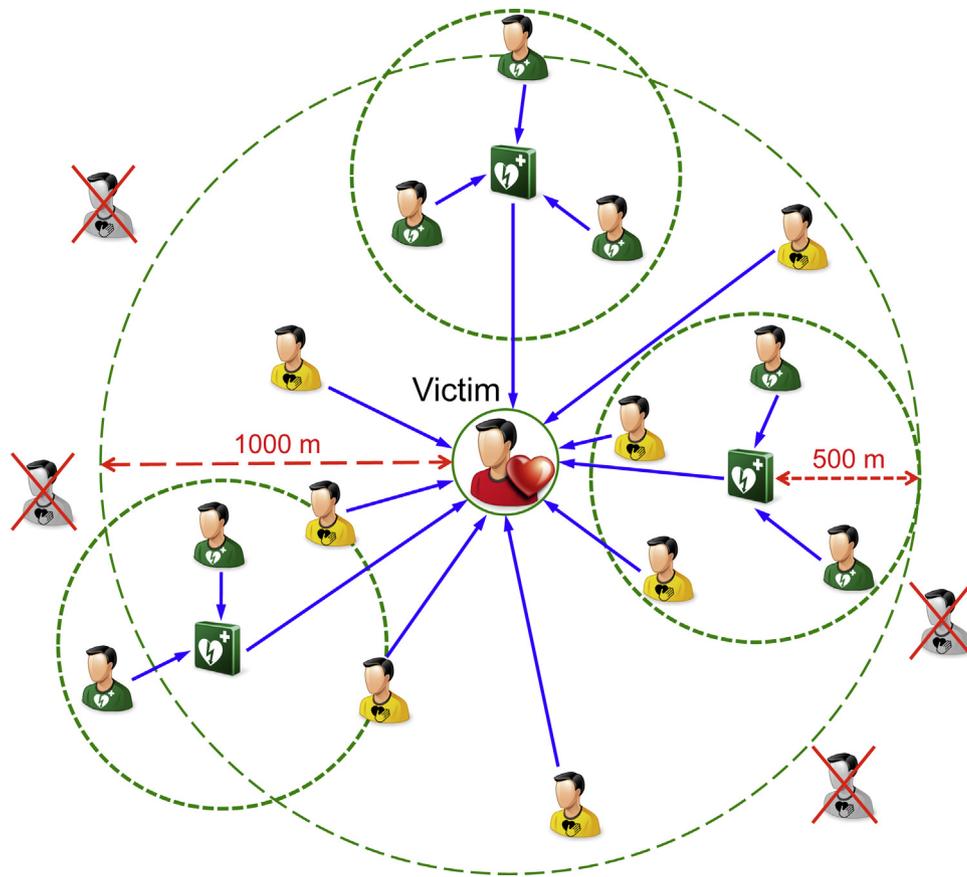
Fig. 1. TM-alert system with the two types of alerted TM-responders. When the dispatcher suspects an OHCA, TM-responders are alerted by text message. The TM-alert system identifies the exact location of the cardiac arrest patient. It generates a flexible circle of maximum 1000 m radius around the patient. Within this circle the system will identify all available TM-responders and all available AEDs. Around each AED another circle with a radius of 500 m is generated. The majority of the TM-responders located within the 500 m circle will receive a text message to retrieve the AED first (dark/green shirts) and then go to the patient's address. Other TM-responders (light/yellow shirts) in the larger circle, will receive a text message to go directly to the patient's address and start CPR. If no AED is found, all TM-responders are immediately directed to the patient. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

download. First recorded rhythm, time of first recorded rhythm and time of first shock were derived from these recordings. Time stamped dispatch data were obtained from the dispatch center.

Delay to connection was the interval between the start of the emergency call and first rhythm visibility of AED or EMS defibrillator recordings. Delay to first shock was the interval between the start of the emergency call and first shock given by either the AED or EMS defibrillator. Some AED brands did not allow viewing of the internal clock. In these cases, time adjustment could be performed if the ECG of the EMS defibrillator was available as well. We then assumed a take-over time of 5 s between the end of the AED ECG tracing and the beginning of the EMS defibrillator ECG tracing.

2.7. Statistical analysis

Statistical analysis was performed with standard software (SPSS version 20.0 for Mac, SPSS Inc., Chicago, IL). Time intervals were expressed as medians (25–75th percentile). Differences between proportions were analyzed with the chi-square test. Mann–Whitney U test was used to compare differences between unpaired groups. All statistical tests were two-tailed and a P-value of <0.05 was considered to indicate statistical significance.

3. Results

During the 42-month study period, EMS personnel attempted to resuscitate 1693 OHCA patients in the TM-alert system area, 1536 of

whom were not witnessed by EMS (Fig. 2). The dispatcher activated the system in 893 of these 1536 (58.1%) cardiac arrests. Table 1 shows the characteristics of cases where the dispatcher decided to activate or to not to activate the system. While non-cardiac causes were more prevalent in non-TM-activated cases, the great majority still had a cardiac cause (84.4% versus 94.5%). An on-site AED was connected more frequently in cases where the TM-alert system was not activated (15.4% versus 7.3%; $P < 0.001$). Median time from emergency call to defibrillator connection was significantly longer (9:28 versus 8:16, min:sec; $P < 0.001$) when the dispatcher did not activate the TM-alert system.

3.1. Who connects the defibrillator first?

Table 2 shows characteristics of patients by type of defibrillator. In the majority of cases (797 of 1536, 51.9%), an AED was connected prior to EMS arrival. Of all connected AEDs, a TM-responder AED was connected in 184 of 797 cases (23.1%). As expected from the goals of the TM-alert system, TM-responder AEDs were connected more frequently to patients in residential areas (161 of 184, 87.5% versus 968 of 1352, 71.6% for all other responders, $P < 0.001$).

At least one AED was included in the TM-alert in 738 cases (Fig. 2). A TM-responder AED was connected in 184 of these cases (24.9%). In 176 of these 184 cases (95.7%) the ECG was retrieved from the AED. A shockable first rhythm was present in 76 (43.2%) of these ECGs. In 76 of all 590 (12.9%) OHCAs with a shockable first rhythm, TM-responder AEDs were the first to give a shock.
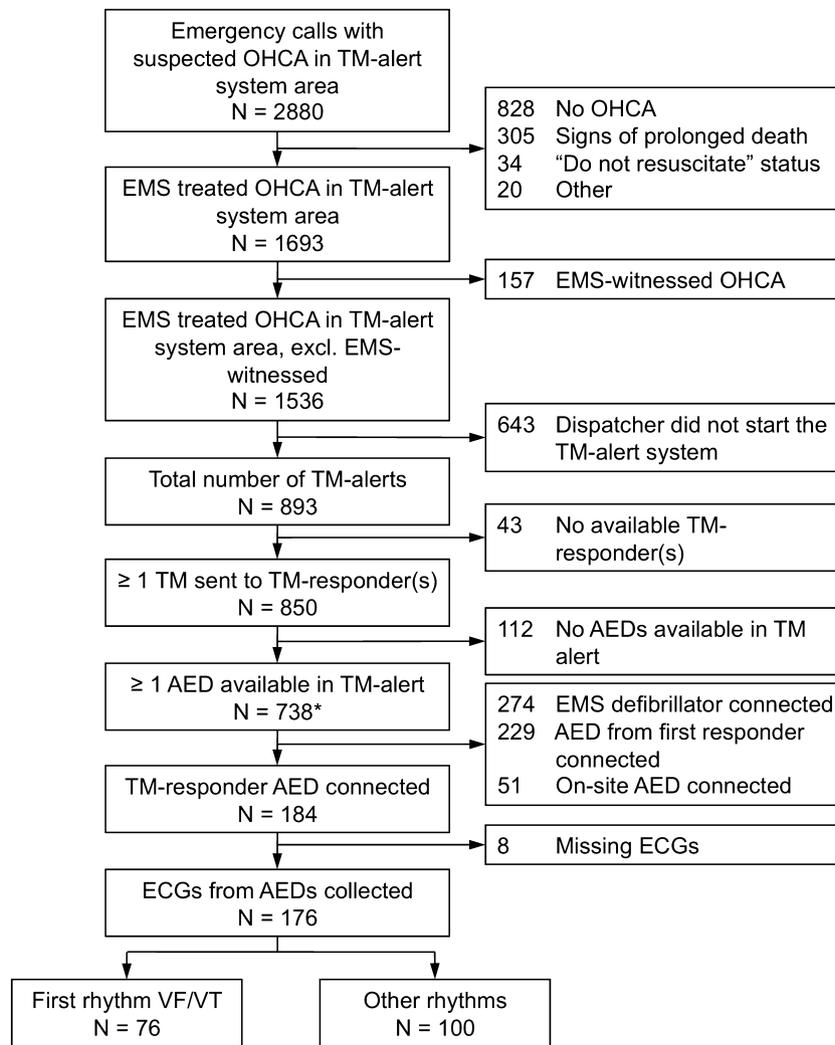
Fig. 2. Deployment of TM-responders and AEDs in TM-alert system. *One TM-responder was sent a text message to go directly to the cardiac arrest patient and start CPR. However, the TM-responder retrieved an AED from the site he/she came from which was not registered in the TM-alert system. OHCA, out-of-hospital cardiac arrest; TM, text message; EMS, emergency medical services; AED, automated external defibrillator; and ECG, electrocardiogram; VF/VT, ventricular fibrillation/ventricular tachycardia.

3.2. Time between emergency call and AED connection/defibrillation

All responders with AEDs shortened the time from emergency call to connection and to defibrillation compared to the EMS group (Table 3). TM-responders decreased time from emergency call to

defibrillator connection significantly by 2:54 (min:sec) compared to EMS ($P < 0.001$), and to first shock by 2:39 (min:sec; $P < 0.001$). TM-responders connected their AED ≤6 min after emergency call in 29 of 176 of cases (16.5%) and defibrillated ≤6 min in 8 of 76 of cases (10.5%) with a shockable first rhythm. In 29 of all 235 connections ≤6 min (12.3%), TM-responders were the first to connect the AED.

Table 1
Factors that could influence EMS's decision to (not) activate the TM-alert system.

	TM-alert system activated N = 893	TM-alert system not activated N = 643	P value
Cause of collapse			<0.001
Cardiac, n (%)	844 (94.5)	543 (84.4)	
Evidently non-cardiac, n (%)	49 (5.5)	100 (15.6)	
Trauma, n (%)	2 (0.2)	37 (5.8)	
Drowning, n (%)	4 (0.4)	10 (1.6)	
Respiratory, n (%)	20 (2.2)	40 (6.2)	
Other, n (%)	23 (2.6)	13 (2.0)	
On-site AED connected, n (%)	65 (7.3)	99 (15.4)	<0.001
Time from call to connection, n, median (25–75th percentile)[a]	801 8:16 (6:36–10:28)	546 9:28 (6:56–12:41)	<0.001
Time from call to 1st shock, n, median (25–75th percentile)[a]	359 8:39 (6:55–11:03)	224 8:39 (6:12–11:22)	0.61

EMS, emergency medical services; TM, text message; and AED, automated external defibrillator.

[a] Time intervals are presented in min:sec.

Table 2
Characteristics of patients with out-of-hospital cardiac arrest by type of defibrillator connected.

First connected defibrillator from	Total $N = 1536$	EMS $N = 739$	First responder $N = 449$	TM-responder $N = 184$	On-site $N = 164$
Mean age in years (SD)	65 (17)	65 (18)	64 (16)	68 (16)	63 (16)
Male gender, n (%)	1083 (70.5)	514 (69.6)	309 (68.8)	130 (70.7)	130 (79.3)
Collapse in residential area, n (%)	1129 (73.5)	585 (79.2)*	330 (73.5)	161 (87.5)*	53 (32.3)
At home, n (%)	1074 (69.9)	561 (75.9)	318 (70.8)	159 (86.4)	36 (22.0)[†]
Residential care/nursing home, n (%)	55 (3.6)	24 (3.2)	12 (2.7)	2 (1.1)	17 (10.4)
Collapse at public location, n (%)	407 (26.5)	154 (20.8)	119 (26.5)	23 (12.5)	111 (67.7)
At work, n (%)	42 (2.7)	17 (2.3)	8 (1.8)	1 (0.5)	16 (9.8)
Street/highway, n (%)	174 (11.3)	84 (11.4)	71 (15.8)	8 (4.3)	11 (6.7)
Place of sports/recreation, n (%)	78 (5.1)	21 (2.8)	15 (3.3)	6 (3.3)	36 (22.0)
Public building, n (%)	100 (6.5)	30 (4.1)	22 (4.9)	7 (3.8)	41 (25.0)
Other, n (%)	13 (0.8)	2 (0.3)	3 (0.7)	1 (0.5)	7 (4.3)
Witnessed collapse, n (%)[‡]	1068 (71.3)	514 (72.0)	294 (66.5)	125 (70.2)	135 (82.8)
Missing, n (%)	39 (2.5)	25 (3.4)	7 (1.6)	6 (3.3)	1 (0.6)
Bystander CPR performed, n (%)[‡]	1225 (81.7)	428 (61.0)	449 (100.0)	184 (100.0)	164 (100.0)
Missing, n (%)	37 (2.4)	37 (5.0)	0 (0.0)	0 (0.0)	0 (0.0)

EMS, emergency medical services; TM, text message; and CPR, cardiopulmonary resuscitation.

* $P < 0.001$ between the TM-responder group and EMS group.

[†] Including AEDs located in apartment buildings and AEDs brought by general practitioners who witnessed the collapse at the patients' home.

[‡] Missing values were not included in the calculation of percentages.

From all first shocks given ≤6 min, 8 of 109 (7.3%) were given by the AED from a TM-responder. On-site AEDs achieved the target of first shock ≤6 min in 62 of 87 (71.3%) of cases.

4. Discussion

This study describes a novel centrally controlled system where text messages are used to jointly activate TM-responders with and without directions to nearby AEDs. Our results suggest that TM-responders with AEDs contribute to a shortening of time to defibrillation compared to EMS. In 12.0% of all OHCAs, they were the first to connect an AED. In 12.3% they were responsible for early connection (≤6 min) and in 7.3% of cases for early defibrillation (≤6 min).

The contribution of TM-responders is limited by the strong involvement of first responders; in 29.2% (449 of 1536), a first responder AED was connected before EMS arrival. Becker et al. found that in only 16.9% of cases (21 of 124) where policemen were dispatched, a police AED was connected prior to ambulance arrival.[13] Saner et al. reported a high percentage of defibrillated patients by a first responder AED. They found that in 75.0% of cases (93 of 124), a first responder AED gave a defibrillation shock. In contrast, an on-site AED provided a defibrillation shock in only 2.4% of cases (3 of 124).[14] We found a lower contribution of first responder AED shocks (178 of 590; 30.2%). However, in our study on-site AEDs or TM-responder AEDs provided a shock in 28.3% (167 of 590) of cases. In their study, EMS teams arrived almost six minutes later than first responders, compared to two and a half minutes in our study.

Improvement of the system by alerting TM-responders based on their exact position (global positioning system [GPS] in smart phones or mobile positioning system [MPS] via provider aerials), may result in faster response and AED connection. It may reduce the required maximum number of alerted TM-responders. Furthermore, a higher density of AEDs and TM-responders could result in earlier AED connection and defibrillation. Nevertheless, without the TM-alert system 7.3% of the cardiac arrest patients whom received an early defibrillation shock would probably not have received a first shock ≤6 min.

The TM-alert system may not only shorten time to a defibrillation shock, it may also promote earlier CPR. For all connected AEDs we know the contribution of TM-alert AEDs, but we do not know who started CPR. It might be that a TM-responder without an AED was the first to start CPR, while a first responder brought the AED.

The TM-alert system was designed to shorten the time between emergency call and initiation of resuscitation (with or without AED use), especially in residential areas. Our results show that almost all TM-responder AEDs (86.4%) were indeed used on patients at home. In contrast, much less on-site AEDs (22.0%) were used on patients at home.

We found that in 643 of 1536 EMS treated OHCAs (41.8%) the dispatcher did not activate the TM-alert system. We indicated several reasons for not activating the system. In 15.6% of cases the collapse had a non-cardiac cause. The decision of the dispatcher not to activate was made correctly in these cases. One of the listed reasons not to activate the system was an expected very short travel time of the dispatched EMS or first responder. Our results suggest that this is an inappropriate reason because the delay to defibrillation was not

Table 3
Time from emergency call to connection and call to first shock in out-of-hospital arrest patients subdivided by type of responder.

First connected defibrillator from	Total $N = 1536$	EMS $N = 739$	First responder $N = 449$	TM-responder $N = 184$	On-site $N = 164$
1st rhythm VF/VT, n (%)*	590 (42.7)	245 (38.7)	178 (44.0)	76 (43.2)	91 (66.0)
Time from call to connection, n, median (25–75th percentile)[†]	1347	631	403	176	137
	8:42 (6:41–11:18)	10:28 (8:21–13:18)[‡]	7:56 (6:29–9:47)	7:34 (6:20–9:13)[‡]	3:46 (1:52–6:29)
Connected ≤6 min, n (%)[†]	235 (17.4)	34 (5.4)	75 (18.6)	29 (16.5)	97 (70.8)
Time from call to 1st shock, n, median (25–75th percentile)[†]	583	245	175	76	87
	8:39 (6:42–11:11)	10:39 (8:18–13:23)[‡]	8:03 (6:43–10:13)	8:00 (6:35–9:49)[‡]	4:06 (2:23–6:40)
1st shock ≤6 min, n (%)[†]	109 (18.7)	6 (2.4)	33 (18.9)	8 (10.5)	62 (71.3)

EMS, emergency medical services; TM, text message; and VF/VT, ventricular fibrillation/ventricular tachycardia.

* Only cases are shown where ECG information was retrieved.

[†] Only cases are shown where ECG information was retrieved and correction for clock drift was possible. Time intervals are presented in min:sec.

[‡] $P < 0.001$ between the TM-responder group and EMS group.

shorter in those cases in which the system was not activated. This indicates that there may be missed opportunities. Another reason for not activating the system is not recognizing the cardiac arrest by the dispatcher. Berdowski et al. found that in 28.8% of the cardiac arrests, the dispatcher did not recognize the cardiac arrest.[15] We believe that this is an important factor, which is difficult to overcome. During the course of the study, standardized protocols for dispatchers were in the process of being implemented. The use of standardized protocols could increase cardiac arrest recognition but could also result in higher false-positive dispatch rates.

In an urban public setting in Stockholm, local lay rescuers (Mobile Life Savers) were alerted to the cardiac arrest site without directions to a nearby AED.[16] In 16.7% of all cardiac arrests, Mobile Life Savers provided CPR prior to EMS arrival. In a Danish program, the dispatch center has an integrated technology which enables them to identify the nearest accessible AED and convey that location to any caller.[17,18] If it is not possible for the caller to retrieve the AED, the dispatcher can contact the AED owner and request that the AED is delivered on-site. In 12.5% of cases, bystanders were referred to an AED.[17] The actual use of AEDs was not reported. Rea et al. also described a dispatch system linked to a public access AED registry.[19] They found that in only 1.2% (9 of 763) of all cardiac arrests, an AED registered with the dispatch center was used. In our study we did not only include urban areas but mid-size cities and small villages as well. Furthermore, our system integrates information of both local lay rescuers and AEDs, and dispatches simultaneously. As a result, a TM-responder AED was connected in 12.0% of all cardiac arrests.

5. Limitations

We have no insight in the exact location of TM-responders at the time of the alert, nor in the number of cases in which a TM-responder responded and started CPR. In an earlier study from 2009 to 2010 of alerted TM-responders, approximately 28% responded.[20] Further developments of mobile phone technology may make this information available and can make the TM-system dispatch more efficient.

6. Conclusions

A mobile phone text message system that included both local lay rescuers and nearby AEDs, contributes to earlier defibrillation in OHCA patients. It addresses a need for early defibrillation in residential areas where the majority of cardiac arrests occur and where public access AEDs usually do not contribute. Its contribution to improved survival needs to be determined with further studies.

Conflict of interest statement

Acknowledgements

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