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Rapid response systems

AED and text message responders density in residential areas for rapid response in out-of-hospital cardiac arrest

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Abstract

Background: For out-of-hospital cardiac arrest (OHCA) in residential areas, a dispatcher driven alert-system using text messages (TM-system) directing local rescuers (TM-responders) to OHCA patients was implemented and the desired density of automated external defibrillators (AEDs) or TM-responders investigated.

Methods: We included OHCA cases with the TM-system activated in residential areas between 2010–2017. For each case, densities/km^2 of activated AEDs and TM-responders within a 1000 m circle were calculated. Time intervals between 112-call and first defibrillation were calculated.

Results: In total, 813 patients (45%) had a shockable initial rhythm. In 17% a TM-system AED delivered the first shock. With increasing AED density, the median time to shock decreased from 10:59 to 08:17 min. ($p < 0.001$) and shocks <6 min increased from 6% to 12% ($p = 0.024$). Increasing density of TM-responders was associated with a decrease in median time to shock from 10:59 to 08:20 min. ($p < 0.001$) and increase of shocks <6 min from 6% to 13% ($p = 0.005$). Increasing density of AEDs and TM-responders resulted in a decline of ambulance first defibrillation by 19% ($p = 0.016$) and 22% ($p = 0.001$), respectively. First responder AED defibrillation did not change significantly. Densities of >2 AEDs/km^2 did not result in further decrease of time to first shock but >10 TM-responders/km^2 resulted in more defibrillations <6 min.

Conclusion: With increasing AED and TM-responder density within a TM-system, time to defibrillation in residential areas decreased. AED and TM-responders only competed with ambulances, not with first responders. The recommended density of AEDs and TM-responders for earliest defibrillation is 2 AEDs/km^2 and >10 TM-responders/km^2.

Keywords: Heart arrest, Ventricular fibrillation, Defibrillation, Cardiopulmonary resuscitation, Lay rescuer, Text message, Automated external defibrillator, AED, First responder, Dispatch, Emergency medical service

Introduction

Early defibrillation is a key determinant of survival of out-of-hospital cardiac arrest (OHCA).[1–5] An automated external defibrillator (AED) allows rescuers to defibrillate prior to ambulance arrival. To increase early defibrillation in out-of-hospital cardiac arrest, AED programs have been introduced including first responder[6,7] and public access defibrillation programs[3,8–12] and have been associated with improved survival in the public domain.[1,2,13–16]

Survival rate of OHCA occurring at home is much lower than the survival rate of OHCA occurring in public.[17] About three-quarters of

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OHCA occurs at home, where publicly accessible AEDs are rarely available. OHCA patients collapsing in residential areas are therefore primarily treated by emergency medical services (EMS), possibly assisted by dispatched first responders with a response time to defibrillation that is only modestly shorter than that of EMS.[4] Consequently, the survival benefit from defibrillation by dispatched first responders is limited.[18]

To shorten the time to defibrillation, particularly in residential areas, a text message (TM) alert system has been developed in The Netherlands. This system is activated by the dispatch center and sends text messages to volunteer rescuers (TM-responders) close to the patient suspected of an OHCA. Two-thirds of the TM-responders receive a text message to retrieve an AED first while the other part is directly send to the patient location.[19]

It is unclear how many AEDs and TM-responders must be included in a program of early defibrillation using volunteer rescuers in order to be successful. The aim of this study was to investigate the required density of available and activated AEDs and of alerted TM-responders needed for early defibrillation in residential areas.

Methods

ARREST-registry

The AmsteRdam REsuscitation STudy (ARREST) is an ongoing prospective registry of all OHCA covering the major part of the province North Holland and the region Twente. For this study, we included two regions: North Holland North and Twente with a total population of 1.27 million inhabitants and similar demographic and geographic characteristics. Routine data collection according to standard methods is described in detail elsewhere.[4,20]

Out-of-hospital cardiac arrest response in The Netherlands

When an OHCA was suspected, the dispatcher simultaneously sent two ambulances and first responders with an AED. Since 2008, a dispatcher driven alert system that used text messages to direct citizen responders directly or via an AEDs to patients with a suspected OHCA has been stepwise implemented.

The TM-system and the citizen responders are described in detail elsewhere.[19,21] Briefly, this system used a database which included the location of registered AEDs and the home and/or work address of TM-responders that volunteered to participate in the system. Anyone who had followed a course in CPR and AED use could register in the system. After activation, the TM-system determined the presence of nearby AEDs and TM-responders in a circle around the patient, starting at the location of the patient, progressive widening up to a maximum of 1000 m (for a short period in some, mostly rural, areas the maximum radius was set to 1500 m) until a maximum of 30 TM-responders were found. A text message with the location of the patient and, when applicable, the AED location was sent to nearby TM-responders. Two-third of the TM-responders were sent to collect a registered AED first, one-third to go to the patient directly and start CPR. By protocol, the TM-system was not activated for suspected OHCA with a traumatic cause and for children with an estimated age below 8 years.

AEDs in the database of the TM-alert system were acquired by local private initiatives or the municipalities. Also, AED owners were

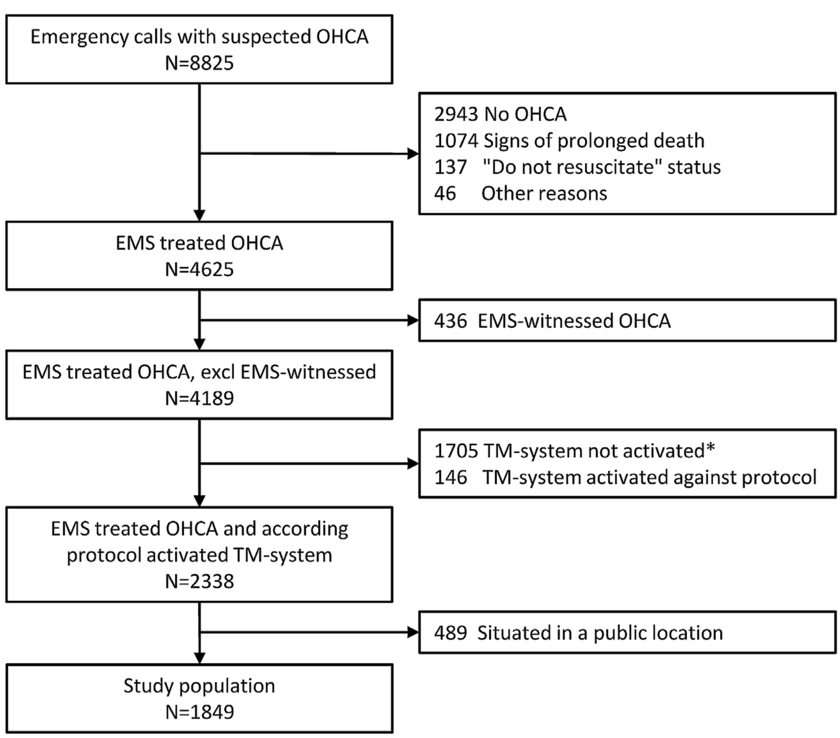

Fig. 1 – Flow of patients.
***Text message alert system not activated because of trauma resuscitation, patient age estimated <8 years, AED onsite available, ambulance (perceived) nearby or out-of-hospital cardiac arrest not recognized by the dispatcher. OHCA indicates out-of-hospital cardiac arrest, EMS emergency medical service and TM-system text message alert system.**

encouraged to move their AEDs to accessible boxes outside their buildings, primarily in residential areas. At the end of the study period, 1931 AEDs and 22,048 TM-responders were registered in North-Holland North and Twente. This corresponds with an average of 0.7 AEDs/km^2 and 7.6 TM-responder/km^2.

Study design

The study included all patients in North Holland North and Twente with an OHCA of (presumed) cardiac cause between February 2010 and December 2017 for which the dispatcher activated the TM-system. We excluded cases if EMS did not start or continue CPR because of prolonged death or absence of cardiac arrest, if the patient had a do not resuscitate declaration, if EMS witnessed the collapse or if the TM-system was not activated by the dispatcher.

The Medical-Ethical Review Board of the Academic Medical Center approved the ARREST data collection and gave a waiver for informed consent.

Data collection and definitions

From all OHCA we collected patient- and resuscitation related data according to standard procedures in the ARREST-study and followed Utstein recommendations.[20] From the EMS we received their ECG

Table 1a – Baseline characteristics of OHCA patients in residential areas, allocated into groups according to the number of activated TM-system AEDs per km^2.

Variable	Total	# AEDs/km^2 (Median)	Number of activated AEDs per km^2				P-value
			0	>0<1	≥1<2	≥2	
All patients—no.	1849		269	605	468	507	
Mean age—yr	68		69	68	67	69	0.739
Male sex—no. (%)[a]	1306 (71%)		196 (73%)	443 (73%)	322 (69%)	345 (68%)	0.046
Bystander witnessed arrest—no. (%)[b]	1228 (68%)		185 (70%)	394 (66%)	303 (67%)	346 (70%)	0.761
CPR started before EMS arrival—no. (%)[c]	1591 (87%)		214 (81%)	543 (91%)	407 (88%)	427 (86%)	0.707
Patient was at home—no. (%)	1797 (97%)		258 (96%)	588 (97%)	456 (97%)	495 (98%)	0.214
Degree of urbanization							
Extreme: ≥2500 addresses /km^2—no. (%)	64 (4%)	1.9	10 (4%)	11 (2%)	14 (3%)	29 (6%)	0.014
Strong: 1500–2500 addresses /km^2—no. (%)	427 (23%)	1.4	45 (17%)	93 (15%)	155 (33%)	134 (27%)	<0.001
Moderate: 1000–1500 addresses /km^2—no. (%)	506 (27%)	1.3	69 (26%)	144 (24%)	143 (31%)	1450 (30%)	0.034
Hardly: 500–1000 addresses /km^2—no. (%)	493 (27%)	1.1	62 (23%)	174 (29%)	114 (24%)	143 (28%)	0.458
None: <500 addresses/km^2—no. (%)	359 (19%)	0.5	83 (31%)	183 (30%)	42 (9%)	51 (10%)	<0.001

P-values were calculated with the Chi-square statistic for trend except for the variable mean age, which was calculated with the Jonckheere–Terpstra test. AED indicates automated external defibrillator, and CPR cardiopulmonary resuscitation.
[a] Data of 2 patients were missing. Percentages were calculated on the basis of the total number of patients, excluding those with missing data.
[b] Data of 37 patient was missing. Percentages were calculated on the basis of the total number of patients, excluding those with missing data.
[c] Data of 25 patients were missing. Percentages were calculated on the basis of the total number of patients, excluding those with missing data.

Table 1b – Baseline characteristics of OHCA patients in residential areas, allocated into groups according to the number of activated TM-responders via an AED per km^2.

Variable	Total	# TM-Responders/km^2 (Median)	Number of activated TM-responders via an AED per km^2				P-value
			0	>0<5	≥5<10	≥10	
All patients—no.	1849		269	563	452	565	
Mean age—yr	68		69	68	66	69	0.921
Male sex—no. (%)[a]	1306 (71%)		196 (73%)	401 (71%)	324 (72%)	385 (68%)	0.159
Bystander witnessed arrest—no. (%)[b]	1228 (68%)		185 (70%)	369 (67%)	306 (69%)	368 (67%)	0.595
CPR started before EMS arrival—no. (%)[c]	1591 (87%)		214 (81%)	512 (92%)	382 (85%)	483 (87%)	0.598
Patient was at home—no. (%)	1797 (97%)		258 (96%)	545 (97%)	442 (98%)	552 (98%)	0.111
Degree of urbanization							
Extreme: ≥2500 addresses /km^2—no. (%)	64 (4%)	8.7	10 (4%)	13 (2%)	18 (4%)	23 (4%)	0.301
Strong: 1500–2500 addresses /km^2—no. (%)	427 (23%)	7.0	45 (17%)	103 (18%)	156 (35%)	123 (22%)	0.005
Moderate: 1000–1500 addresses /km^2—no. (%)	506 (27%)	7.3	69 (26%)	127 (23%)	127 (28%)	183 (32%)	0.001
Hardly: 500–1000 addresses /km^2—no. (%)	493 (27%)	7.2	62 (23%)	136 (24%)	115 (25%)	180 (32%)	0.002
None: <500 addresses/km^2—no. (%)	359 (19%)	2.2	83 (31%)	184 (33%)	36 (8%)	56 (10%)	<0.001

P-values were calculated with the Chi-square statistic for trend except for the variable mean age, which was calculated with the Jonckheere–Terpstra test. AED indicates automated external defibrillator, and CPR cardiopulmonary resuscitation.
[a] Data of 2 patients were missing. Percentages were calculated on the basis of the total number of patients, excluding those with missing data.
[b] Data of 37 patient was missing. Percentages were calculated on the basis of the total number of patients, excluding those with missing data.
[c] Data of 25 patients were missing. Percentages were calculated on the basis of the total number of patients, excluding those with missing data.

Table 2a – Radius of the alert and defibrillation characteristics of OHCA patients in residential areas, allocated into groups according to the number of activated TM-system AEDs per km^2.

Variable	Total	Number of AEDs per km^2 activated				P-value
		0	>0<1	≥1<2	≥2	
All patients—no.	1849	269	605	468	507	
Radius of the alert in meters—median (IQR)	997 (750, 1000)	1000 (995, 1000)	1000 (1000,1315)	916 (776,1000)	653 (524,756)	
First defibrillator connection[a]						
By EMS defibrillator—no. (%)	845 (46%)	165 (61%)	259 (43%)	206 (44%)	215 (42%)	<0.001
By TM-responder—no. (%)	331 (18%)	6 (2%)[d]	136 (23%)	86 (18%)	103 (20%)	<0.001
By first responder AED—no. (%)	628 (34%)	95 (35%)	191 (32%)	164 (35%)	178 (35%)	0.536
By onsite AED—no. (%)	45 (2%)	3 (1%)	19 (3%)	12 (3%)	11 (2%)	0.829
Shockable initial rhythm—no. (%)[b]	813 (45%)	124 (48%)	274 (46%)	206 (45%)	209 (42%)	0.102
First shock given on shockable initial rhythm[c]						
By EMS defibrillator—no. (%)	379 (47%)	78 (63%)[e]	115 (42%)	95 (46%)	91 (44%)	0.016
By TM-responder—no. (%)	139 (17%)	3 (2%)[d]	63 (23%)	35 (17%)	38 (18%)	0.045
By first responder AED—no. (%)	280 (35%)	41 (33%)	90 (33%)	72 (35%)	77 (37%)	0.387
By onsite AED—no. (%)	13 (2%)	1 (1%)	5 (2%)[f]	4 (2%)	3 (1%)	0.792

P-values were calculated with the Chi-square statistic for trend. AED indicates automated external defibrillator, IQR interquartile range, EMS emergency medical services and TM-responder text message responder.

[a] Percentages were calculated on the basis of the total number of patients, excluding 11 patients with missing data.

[b] Percentages were calculated on the basis of the total number of patients, excluding 37 patients with missing data.

[c] Percentages were calculated on the basis of the total number of patients, excluding 5 patients with missing data.

[d] Six times a text message responder received a text message to directly go to the patient and start CPR, but collected a not registered AED from the place where he was at the moment of the text message alert.

[e] In 1 patient with a shockable initial rhythm (VT) EMS decided to not give any defibrillation shock.

[f] In 1 patient with a shockable initial rhythm, the AED and EMS had not given any defibrillation shock because of an active ICD which gave 9 shocks in total.

Table 2b – Radius of the alert and defibrillation characteristics of OHCA patients in residential, allocated into groups according to the number of activated TM-responders directed to an AED per km^2.

Variable	Total	Number of TM-responders via an AED per km^2 activated				P-value
		0	>0<5	≥5<10	10	
All patients—no.	1849	269	563	452	565	
Radius of the alert in meters—median (IQR)	997 (750, 1000)	1000 (995, 1000)	1130 (1000,1361)	952 (851,1000)	672 (544,750)	
First defibrillator connection[a]						
By EMS defibrillator—no. (%)	845 (46%)	165 (61%)	247 (44%)	205 (45%)	228 (40%)	<0.001
By TM-responder—no. (%)	331 (18%)	6 (2%)[d]	112 (20%)	67 (15%)	146 (26%)	<0.001
By first responder AED—no. (%)	628 (34%)	95 (35%)	186 (33%)	170 (38%)	177 (31%)	0.429
By onsite AED—no. (%)	45 (2%)	3 (1%)	18 (3%)	10 (2%)	14 (3%)	0.663
Shockable initial rhythm—no. (%)[b]	813 (45%)	124 (48%)	257 (47%)	204 (46%)	228 (41%)	0.050
First shock given on shockable initial rhythm[c]						
By EMS defibrillator—no. (%)	379 (47%)	78 (63%)[e]	114 (44%)	94 (46%)	93 (41%)	0.001
By TM-responder—no. (%)	139 (17%)	3 (2%)[d]	51 (20%)	33 (16%)	52 (23%)	<0.001
By first responder AED—no. (%)	280 (35%)	41 (33%)	86 (34%)	73 (36%)	80 (35%)	0.623
By onsite AED—no. (%)	13 (2%)	1 (1%)	6 (2%)	3 (2%)[f]	3 (1%)	0.874

P-values were calculated with the Chi-square statistic for trend. AED indicates automated external defibrillator, IQR interquartile range, EMS emergency medical services and TM-responder text message responder.

[a] Percentages were calculated on the basis of the total number of patients, excluding 11 patients with missing data.

[b] Percentages were calculated on the basis of the total number of patients, excluding 37 patients with missing data.

[c] Percentages were calculated on the basis of the total number of patients, excluding 5 patients with missing data.

[d] Six times a text message responder received a text message to directly go to the patient and start CPR, but collected a not registered AED from the place where he was at the moment of the text message alert.

[e] In 1 patient with a shockable initial rhythm (VT) EMS decided to not give any defibrillation shock.

[f] In 1 patient with a shockable initial rhythm, the AED and EMS had not given any defibrillation shock because of an active ICD which gave 9 shocks in total.

data and run reports. Study personnel downloaded data from used AEDs and synchronized the time of the recording with a network time. We recorded if a TM-alert was sent, the used radius of the circle around the patient, how many available AEDs were found and how many TM-responders were alerted to fetch an AED first. From this we calculated the density of activated AEDs and TM-responders send via an AED per km^2. It was not documented how many TM-responders had actually responded and what assistance they had given, other than AED use. For each location of a patient the level of urbanization was determined from the national statistics database, subdivided into five levels of urbanization: <500, 500–1000, 1000–1500, 1500–2500 or ≥2500 addresses/km^2, respectively.[22]

A shockable rhythm was defined as ventricular fibrillation or rapid and pulseless ventricular tachycardia, verified from the downloaded defibrillator recordings or EMS reports. For early defibrillation, the definition of the Dutch Heart Foundation was used, which states that a defibrillation shock should be given within 6 min after collapse (as the exact time of collapse is unknown, we use the time of call to the dispatch center as starting point). A TM-responder was any volunteer who participated in the TM-system and who was alerted to the scene. Residential areas were private homes or apartment buildings, including other residential institutions like nursing homes and old-age homes.[17]

Outcomes and data analysis

We determined the time intervals between the call to the dispatch center and the time to connection and to defibrillation of an AED or ambulance defibrillator.

For trend analysis of time intervals in relation to AED or TM-responder density we performed the Jonckheere-Terpstra test because the densities are ordered from low to high. To test the trend in the proportion of patients defibrillated within six minutes we calculated the Chi-square statistic for trends. All data were analysed using the statistical software package SPSS (SPSS for Windows, version 25.0, IBM SPSS Inc.). P-values < 0.05 were considered statistically significant.

Results

During the study period the dispatch centers received 8825 calls concerning a suspected OHCA. Patients included and excluded of the analysis are shown in Fig. 1. In 56% of all EMS treated OHCA the dispatcher decided to activate the TM-system. A majority of 79% of these cases were in residential areas. The final study population included 1849 patients. For all cases where at least 1 registered AED was found, the mean densities were 1.8 AED per km^2 and 10.9 TM-responders per km^2.

Tables 1a and 1b show the patient characteristics and urbanization within four strata of AED densities and four strata of TM-responders densities. These strata were comparable for patient characteristics. The higher the degree of urbanization, the higher the probability of finding more AEDs and TM-responders within the circle ($p < 0.001$).

Overall, TM-responders with an AED were the first to connect their AED in 18% and to defibrillate first in 17% of all cases with a shockable initial rhythm. The probability that a TM-responder was the first to connect an AED or defibrillate was associated with the density of AEDs included in the TM-alert (p for trend <0.001 and 0.045, respectively) (Table 2a). Increasing density of TM-responders within the circle led to a significantly higher proportion of connected AEDs and defibrillation by the TM-responders as well (both p for trend <0.001) (Table 2b). If at least one TM-responder via an AED was alerted, the chance that EMS was the first to defibrillate decreased from 63% to 44% (p for trend <0.001). The contribution of first responders and onsite AEDs to connection and defibrillation remained unchanged with increasing density of TM-responders and AEDs.

AED and TM-responder density was associated with a decrease in the median time to connection and first defibrillation (Figs. 2 and 3). With increasing AED or TM-responder density, the time interval to connection (Fig. 3a and b) and defibrillation (Fig. 3c and d) shortened significantly (p for trend <0.001). When the AED density exceeded 2 AEDs/km^2 or TM-responder density exceeded 10 TM-responders/km^2, time to connection

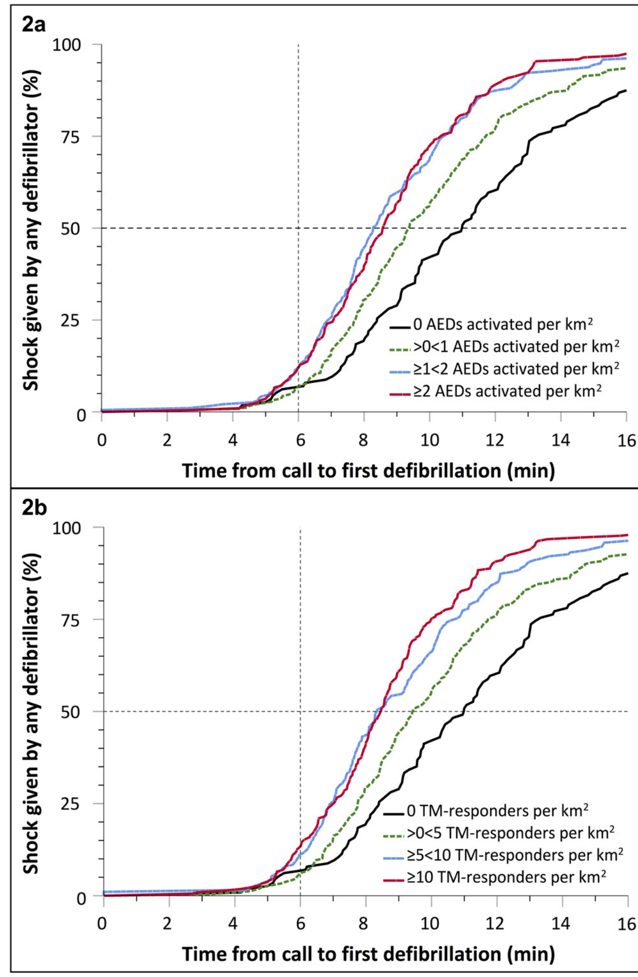

Fig. 2 – Cumulative time interval between emergency call and the first defibrillation shock, for groups according to the density of activated text message AEDs (2a) and activated text message responders directed to an AED (2b).
AED indicates automated external defibrillator and TM-responder text message responder.
The cumulative percentage is >0% at 0 min, because onsite AEDs could already provide a defibrillation shock before the dispatch center was called.

and defibrillation did not further decrease. The probability to defibrillate within 6 min increased significantly with even higher TM-responder density (Fig. 3f) (p for trend 0.005).

We found similar results when we divided the cohort into day time (07.00–21.59) and night time (22.00–06.59). The percentage of connected system AED at day time (22%) was slightly higher then at night time (17%) when at least one AED or TM-responder via an AED was alerted. All response times were approximately 1 min median longer during night time as during day time.

Discussion

We evaluated the use of a TM-system in residential areas directing trained volunteer rescuers directly or via an AED to nearby patients with

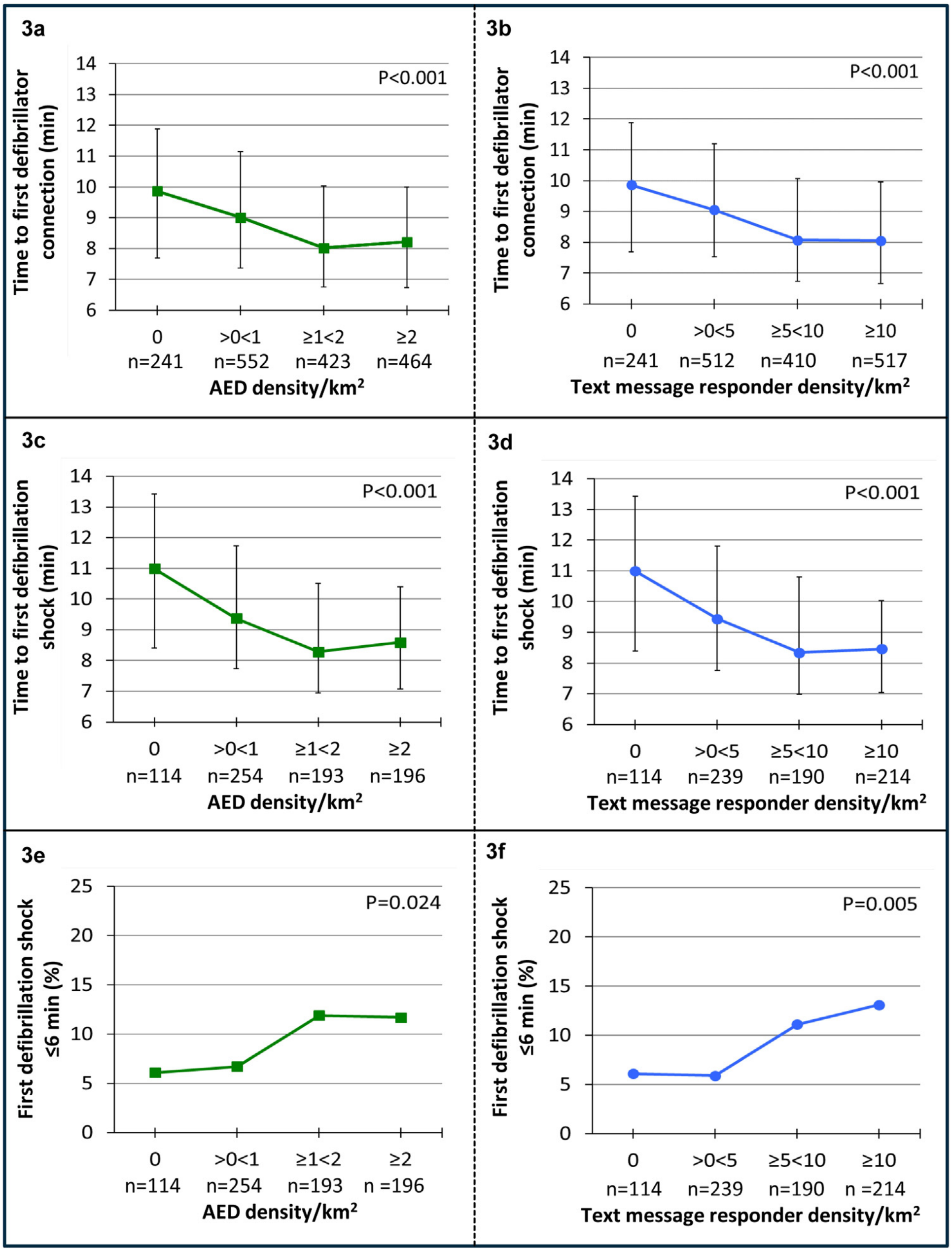

Fig. 3 – AED (Left Panels) and TM-responder (Right Panels) density per km^2 and time to defibrillation. a–b show the median time from the emergency call to the first defibrillator connection. c–d show the median time from the emergency call to the first defibrillation shock. The proportion of patients who were shocked ≤6 min after emergency call are shown in e and f. Bars indicate the 25th–75th percentile of the time interval between call to the dispatch center and defibrillation.

AED indicates automated external defibrillator.

Statistics: For a–d we used the Jonckheere–Terpstra test for trend. For e and f we used the p for trend.

an OHCA. Our study shows that if at least one TM-responder was directed via an AED, the time to the first defibrillation shock decreased. There was a significant 'dose-response' relationship between the density of available TM-responders or AEDs and early defibrillation. A density of 2 AEDs or >10 TM-responders available per km^2 resulted in the shortest time to defibrillation. Higher densities did not result in additional shortening of this time. The number of patients that were defibrillated ≤6 min doubled when there were at least 1–2 AEDs or ≥10 TM-responders per km^2 directed to a registered AED (Fig. 3e and f). Given the steeper slope of the survival curve in the early minutes after collapse, this early time gain probably has a larger impact on survival than the same time gain later after collapse, but this was not analysed in this study. The decrease in proportion of defibrillation by EMS approximately matched the proportion of cases where a TM-responder performed the first defibrillation. Therefore, it seems that TM-responders are not replacing other first responders, but act complementary to them, only replacing the slower EMS (Tables 2a and 2b).

The median radius of the circle in our system before the required 30 TM-responders were found was 997 m (Tables 2a and 2b). This is more than 1–1.5 min brisk walking that corresponds with a distance of 100–150 m between the victim and an AED as recommended in early studies.[23] The TM-system used a smaller circle if the densities of AEDs and TM-responders were higher, down to a median radius of 653 and 672 m in the highest category of AED and TM-responders density, respectively. It is important to note that the circle radius was set to find the maximum of 30 TM-responders. As soon as 30 TM-responders were found, the system stopped searching and the radius was set at the distance of the farthest activated TM-responder. In case there were less than 30 TM-responders found, the system used the maximum set radius. We had no information of the distance to the victim of the first arriving TM-responder.

In a study from Copenhagen the density of network AEDs in public in 2011 was 16 AEDs/km^2 for high and low risk areas for OHCA, compared with 0.7 AEDs/km^2 in our residential study.[24] Nevertheless, in Copenhagen 25% of 109 patients with OHCA were covered by a network AED (<100 m from a patient) and 6 (6%) AEDs were connected to a patient. In our study, 85% of the 1849 patients were covered by a TM-system AED (minimally 1 AED mentioned in the TM-alert) and in 18% of all a TM-alert AED was connected. This indicates that the TM-system in our study can attach an AED to a higher proportion of patients with a much lower density of AEDs. In Copenhagen the bystander needs to cover the same distance twice, while in the Netherlands the TM-responder travels one way only and AEDs can be brought from a larger distance within the same time. Hence, in the Dutch setting a single AED can cover a larger area than in the Copenhagen setting, with the same or higher "efficiency". Also, more TM-responders and AEDs are involved in a single rescue effort.

Another study from Copenhagen with a two-way transport method showed similar results.[25] The chance of bystander defibrillation in public and residential areas if an AED was available within 100 m was 23% (32% in public, 4% in residential areas) and that number declined rapidly as the distance to the nearest AED was more the 100 m.

A novel element in the system was the algorithm in the TM-system that created a 'dual-dispatch': directing two-thirds of the TM-responders to an AED first and one-third directly to the patient to start CPR, which contributes not only to early defibrillation but to early initiation of CPR by trained rescuers as well.

Our results suggests that in the current TM-system, AED densities >2/km^2 might not improve the probability for a TM-system AED to be the first to get attached or the chance of early defibrillation. However, AED densities <1/km^2 definitely have a negative effect on the time to first shock by a TM-system AED. TM-responder density >10/km^2 increased very early (<6 min) defibrillation. This suggests that other factors are important as well, such as "rescuer start-up delay", finding and opening an AED box and fixing electrodes at the chest. Therefore, these densities should not be regarded as a optimum but as a recommended goal. The aim to reduce time to shock by the TM-system need not only concentrate on the AED but at TM-responder availability as well. New solutions, such as an automatic software driven activated alert system and the use of a smartphone application that can alert TM-responders based on their actual GPS-based location and guide them to the AED and victim, may improve conditions for early defibrillation even more without the need to increase density of AEDs and TM-responders.

Strength and limitations of the study

Our study gives a perspective of the added value of TM-responders, taking in consideration an already well-developed existing response system. A unique property of our data collection is the precise quantification of the time to AED/EMS connection and defibrillation in the total response system from time stamped and clock drift corrected data from all defibrillators. This gives an insight of the true delay, better than "vehicle stop" as crude proxy, which may underestimate the arrival time at the patient's side by several minutes.

Our study has several limitations. First, during the study, the system was ony able to use the registered home- and work address to alert TM-responders, instead of using the actual GPS determined location, which became available after the study period. Second, we have no information about the number of TM-responders that actually responded to the TM-alert, nor the distance of each TM-responder to the victim within the circle at the moment of receiving the text message. Questionnaire based studies in our region showed that one-third of all TM-responders responded to the alert.[21,26] We also have no insight if the TM-responder was the one who initiated bystander CPR. Therefore we cannot be certain that dispatching TM-responders directly to the patient, explains the higher proportion of bystander CPR. Third, in this study, there was no information available on the geographical layout of the OHCA locations (e.g. family houses or high apartment buildings), which may have some effect on the density of AEDs and TM-responders needed.

Conclusion

The recommended density of AEDs and TM-responders for an effective TM-alert system for OHCA patients in residential areas appears to be when two AEDs and at least 10 TM-responders per km^2 were available for dispatch. For an effective TM-system, one should not only concentrate on AED availability but at TM-responder availability as well.

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Disclosures

RWK is receiver of the research grants that funded this study. He is a medical advisor for Stryker Emergency Care and HeartSine (Belfast, Northern Ireland, UK). The other authors declare no potential conflicts.

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