

# Factors modifying performance of a novel citizen text message alert system in improving survival of out-of-hospital cardiac arrest

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## Abstract

**Aims:** Recently we found that the text message alert system increases survival of sudden out-of-hospital cardiac arrest. The aim of the present study is to explore the contribution of the system to survival specifically in resuscitation settings with prolonged delay of start of resuscitation.

**Methods and results:** Data were used from consecutive patients resuscitated for out-of-hospital cardiac arrest during a two-year period in the Dutch province Limburg. Survival of 291 cases with out-of-hospital cardiac arrest where one or more volunteers attended (Scenario 2) was compared with survival of 131 cases with out-of-hospital cardiac arrest where no volunteers attended and only standard care was given (Scenario 1). Multivariable logistic regression models including terms for interaction between scenario and the covariate coding for resuscitation setting were used to test for effect modification. The highest impact on survival of the alert system was observed in cases of (a) witnessed arrests (odds ratio=2.25; 95% confidence interval: 1.27–4.00;  $p=0.005$ ); (b) arrests that occurred in the home (odds ratio=2.28; 95% confidence interval: 1.21–4.28;  $p=0.011$ ); (c) arrival of the ambulance with a delay of 7–10 min (odds ratio=2.63; 95% confidence interval: 1.09–6.35;  $p=0.032$ ); and (d) arrests at evening/night (odds ratio=3.07; 95% confidence interval: 1.34–7.03;  $p=0.008$ ). Due to the low sample size,  $p$ -values from tests for interaction were non-significant.

**Conclusion:** The contribution of the alert system to survival is most substantial in cases of witnessed arrest, in the home situation, at slightly delayed arrival of the first ambulance and during the evening/night.

## Keywords

Survival, heart arrest, cardiopulmonary resuscitation, registry, effect modifiers

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## Introduction

To improve outcomes of sudden out-of-hospital cardiac arrest (OHCA), a novel citizen alert system was implemented in several regions in the Netherlands. Besides activating two ambulances, the dispatch centre also notifies citizen volunteers by text message (TM). Within their zip code vicinity, those volunteers are requested to go to the presumed arrest and either start basic life support (BLS) or first get an automated external defibrillator (AED).

Recently, we performed a study in the Dutch province Limburg to assess the value of this system.<sup>1</sup> If the system

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was activated but no volunteer responded (Scenario 1) then only standard care was given, and therefore this scenario was used as the reference group. It was found that survival to hospital discharge substantially increased from 16.0% to 27.1%, when at least one volunteer responded (Scenario 2) to the notification.<sup>1</sup>

In the study at hand we aimed to explore the contribution of the alert system to survival specifically in situations with prolonged delay of start of resuscitation. The rationale behind the system is that responders can contribute to survival because they help to reduce the period between onset of the arrest and start of cardiopulmonary resuscitation (CPR) sufficiently soon after the collapse. Therefore, it was hypothesised that the system is most effective in situations where there may be a delay in response time, such as in the home or at night, and longer ambulance arrival times. Furthermore, a reduction of response time was expected to be especially effective in witnessed victims, because in unwitnessed victims help and support may often come too late anyway.

## Methods

### Setting

The details of the study design and system have been published previously.<sup>1</sup> From April 2012–April 2014, a prospective registry included all OHCA in the Dutch province of Limburg. The study region Limburg has an area of approximately 2153 km<sup>2</sup> (831 mi<sup>2</sup>) and consists of 1.12m inhabitants. Approval for the study was obtained from the medical ethics committee of the Maastricht University Medical Centre (project number 114029).

### Resuscitation volunteer network in the study region

Throughout the Netherlands, two ambulances are dispatched in the case of an (suspected) OHCA, each ambulance including one paramedic and a driver with CPR skills. A network of BLS/AED certified volunteers was implemented throughout Limburg and other regions in the Netherlands in order to reduce the delay in response time to start CPR. Furthermore, registered network AEDs were placed specifically in residential areas. Using the zip code derived location of the arrest location and volunteers, the dispatch centre notifies volunteers, close to the OHCA, simultaneously with two ambulances. In a 1:2 fashion, zip code identified volunteers within a radius of 1 km (0.62 mi) of the OHCA are notified to either start BLS or to get an AED first by the nearest network. During the study period, the alert system was active in 17 of the 24 Dutch dispatch centres and included 61,000 registered volunteers. The system was implemented in both dispatch centres in Limburg with more than 9000 volunteers

(8.3/1000). The response rate of volunteers is not predictable and depends on the number of volunteers in the specific zip code area and their actual availability. A maximum of 30 volunteers are notified to make sure a sufficient but not excessive number of volunteers responds to the notification.

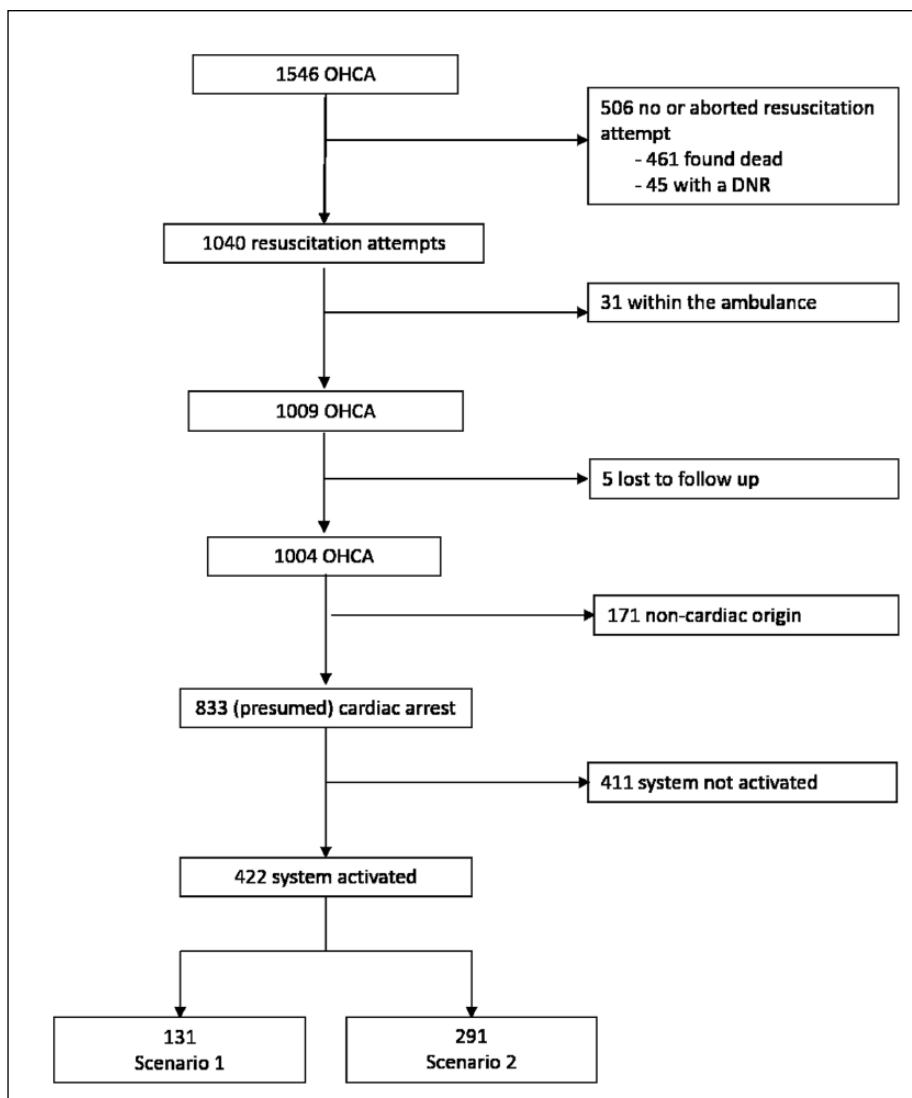
### Data collection

Data were used from a registry of all consecutive OHCAs which occurred during a two-year period (April 2012–April 2014) in the Dutch province of Limburg. Data were collected according to the Utstein template.<sup>2–4</sup> On a daily basis, all emergency calls were screened for suspected OHCAs. The data consisted of notification time, ambulance departure time and arrival time at the location, departure time to and arrival time at the hospital, patient's condition and treatment. Information was also obtained from the paramedic notes about the resuscitation scenario (e.g. whether the OHCA was witnessed or not, who started CPR and the sequence of laymen and professionals that attended the OHCA). The alert system organisation (Hartslagnu) provided information about the activation of the system, such as the time the TM was sent, the number of notified volunteers and AEDs, and type of notification (start BLS or first get an AED). All notified volunteers received a questionnaire to obtain information about their attendance and, if applicable, about details of the scenario. Information included the presence of a witness and the start of CPR by the witness or by a bystander. Importantly, a witness was defined as the one who saw, heard or monitored the OHCA. A bystander was defined as the one who did not witness the event but was at the scene as well (e.g. a neighbour called by the witness). From the six hospitals in the province of Limburg information was gathered about post-resuscitation treatment, clinical outcome and discharge date and, if available, the medical history before OHCA.

In this study, survival was compared between two resuscitation scenarios. In Scenario 1, the system was activated but no volunteer attended at the scene. In this situation, survival depended on standard care available from the two ambulances directed to the OHCA. In Scenario 2, the system was activated and volunteers indeed responded. The primary outcome measure was the proportion of patients surviving until discharge from hospital.

### Statistical analysis

OHCA cases were categorised into subgroups according to whether the OHCA was witnessed, the location of the arrest, the time until arrival of the first ambulance and the time of day. Proportions of patients surviving until hospital discharge and relative risk estimates of survival with 95% confidence intervals (CIs), using Scenario 1 as the



**Figure 1.** Flowchart of patient inclusion. Scenario 1, system activated 0 responders; Scenario 2, system activated  $\geq 1$  responder. DNR: do not resuscitate policy; OHCA: out-of-hospital cardiac arrest.

reference category, were calculated within subgroups (strata) which are referred to as stratum-specific odds ratios (ORs). Multivariable logistic regression analyses including scenario, the covariate coding for resuscitation setting and an interaction term for both variables were used to test for effect modification. Exponentiation of the regression coefficient corresponding with the interaction term gives the interaction OR. The interaction OR indicates whether the gain in survival due to the volunteer system differs between resuscitation settings (witnessed or not, location, arrival time of ambulance and time of day). An interaction OR=1 indicates equal survival benefit across strata. An interaction OR=2 indicates doubling of survival benefit compared to the reference category and for example an interaction OR=0.50 indicates halving of survival benefit compared to the reference category. Values of  $p \leq 0.05$  were considered statistically significant. For the analyses the software

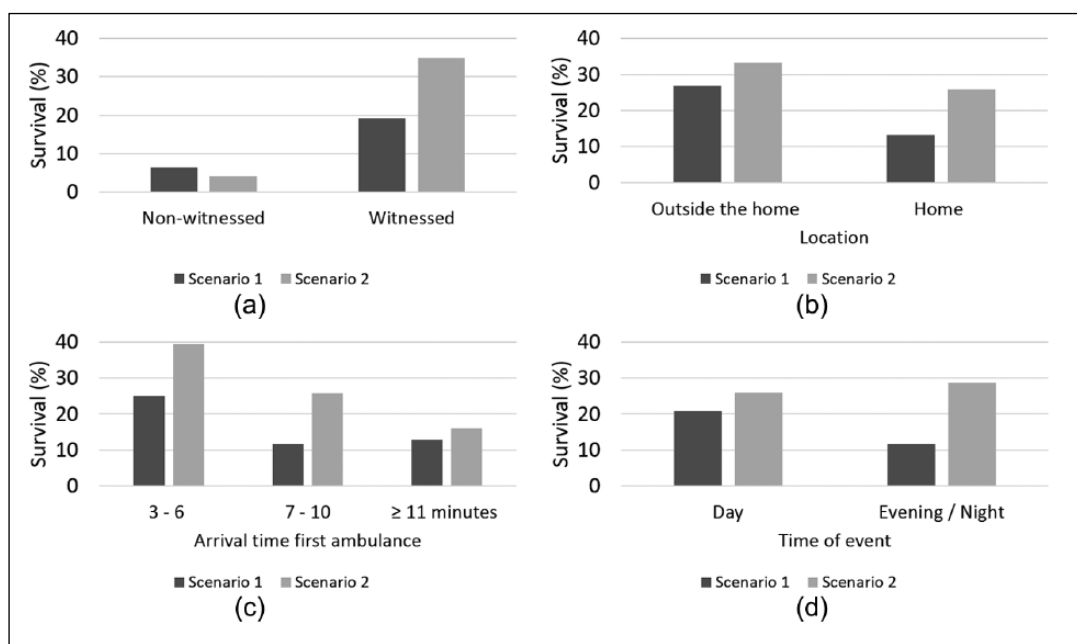
package of SPSS (SPSS for Windows, version 22.0, SPSS Inc., Chicago, Illinois, USA) was used.

## Results

The study population has been described previously.<sup>1</sup> During the 24-month study period a total of 833 victims had (presumed) cardiac arrest. The system was activated in 422 (50.7%) cases and not activated in 411 (49.3%) cases. If the system was not activated, this was mostly because an ambulance was nearby or present at the scene, or because the OHCA occurred in a (closed) public place with an on-site AED (such as shopping malls). For this study, only data from system-activated cases were used where one or more volunteers responded in 291 cases (Scenario 2) and no volunteers responded in 131 cases (Scenario 1) (see Figure 1). Scenario 1 was used as the reference group.

**Table 1.** Percentages of survivors per scenario and total numbers (%) within strata according to witness status, location, time until arrival of first ambulance and time of day.

	Scenario 1	Scenario 2	Number (%)
Witnessed, no. (%), n=422			
No	2/32 (6.3)	3/73 (4.1)	105 (24.9)
Yes	19/99 (19.2)	76/218 (34.9)	317 (75.1)
Location of the arrest, no. (%), n=422			
Outside the home	7/26 (26.9)	16/48 (33.3)	74 (17.5)
Inside the home	14/105 (13.3)	63/243 (25.9)	348 (82.5)
Time until arrival of first ambulance, no. (%), n=412			
≤6 min	9/36 (25.0)	30/76 (39.5)	112 (27.2)
7–10 min	7/60 (11.7)	33/128 (25.8)	188 (45.6)
≥11 min	4/31 (12.9)	13/81 (16.0)	112 (27.2)
Time of day, no. (%), n=422			
Day	13/62 (21.0)	42/162 (25.9)	224 (53.1)
Evening/night	8/69 (11.6)	37/129 (28.7)	198 (46.9)

**Figure 2.** Percentages of survivors in the cardiopulmonary resuscitation (CPR) groups among the subgroups. Scenario 1 indicates the system activated no responders; Scenario 2 indicates the system activated with  $\geq 1$  responder.

### Distribution of resuscitation settings

Mean age was 68.1 years (standard deviation (SD) $\pm$ 13.6) and 71.6% of OHCA victims were male. OHCA was witnessed in 75.1% of cases, and took place in the home situation in 82.5% of the cases. About 53.1% of the OHCAs occurred during the day vs 46.9% at evening or night (Table 1). In about 75% of cases the ambulance arrived after six minutes. The mean number of responding volunteers was 2.8 at daytime vs 2.9 at evening/night.

Scenario 1 indicates that the system was activated but no volunteers responded. Scenario 2 indicates that the system was activated and at least 1 volunteer responded. In case

OHCA was witnessed, the majority of the OHCAs (92.7%) occurred in at least one of the following settings: (a) in the home or (b) the arrival time of the first ambulance was between 6–11 min or (c) during the evening/night.

### Contribution of the responder to survival in different situations

Figures 2(a)–(d), and Table 1 display the percentages of survival until discharge within strata of victims according to whether the OHCA was witnessed (yes or no), the location (inside vs outside the home), arrival time of the first ambulance (6, 7–10 or  $\geq 11$  min) and time of day (08:00–18:00 vs

**Table 2.** Relative risk estimates and interaction odds ratios (ORs) of survival at hospital discharge in Scenario 2 according to witnessed arrest (yes or no), location, time until arrival of first ambulance and period of the day.

Setting	Stratum specific OR (95% CI)	p-Value	Interaction OR (95% CI)	p-Value
<b>Witnessed</b>				
No	0.64 (0.10–4.05)	0.638	1.00 (reference)	–
Yes	2.25 (1.27–4.00)	0.005	3.51 (0.51–24.07)	0.202
<b>Location</b>				
Outside the home	1.36 (0.47–3.89)	0.570	1.00 (reference)	–
Home	2.28 (1.21–4.28)	0.011	1.68 (0.49–5.73)	0.410
<b>Arrival times</b>				
≤6 min	1.96 (0.81–4.73)	0.137	1.00 (reference)	–
7–10 min	2.63 (1.09–6.35)	0.032	1.34 (0.39–4.69)	0.642
≥11 min	1.29 (0.39–4.31)	0.679	0.66 (0.15–2.94)	0.585
<b>Period of the day</b>				
Day	1.32 (0.65–2.67)	0.441	1.00 (reference)	–
Evening/night	3.07 (1.34–7.03)	0.008	2.33 (0.78–6.91)	0.129

CI: confidence interval.

18:00–08:00). Table 2 shows stratum-specific and interaction odds ratios. The data show that the system leads to survival benefit within all strata except for the subgroup of non-witnessed arrests.

**Witnessed and non-witnessed arrests.** In both scenarios, witnessed arrests were associated with a better survival probability compared to non-witnessed OHCA (Table 1). In the presence of volunteers the survival rate of witnessed OHCA increased from 19.2% (Scenario 1) to 34.9% (Scenario 2) corresponding with an OR=2.25 (95% CI: 1.27–4.00;  $p=0.005$ ). During a non-witnessed arrest the attendance of volunteers was not associated with gain in survival (Table 1) corresponding with an OR=0.64 (95% CI: 0.10–4.05;  $p=0.638$ ). The OR for interaction is 3.51 (95% CI: 0.51–24.07) meaning that the survival benefit due to the volunteer system is 3.5 times higher for witnessed arrests than for non-witnessed arrests. The  $p$ -value for interaction is 0.202.

**Location of the arrest.** As expected, the system was mainly activated in cases occurring in the home (348/422) but activation also occurred in 74 cases outside the home. For both Scenario 1 and Scenario 2 survival was higher outside the home than in the home (Table 1, Figure 2(b)). However, within the home, survival in Scenario 2 almost doubles compared to Scenario 1 (25.9% vs 13.3%) whereas outside the home survival in Scenario 2 is not much increased (33.3% vs 26.9%). As depicted in Table 2, stratum-specific relative risk estimates (favouring Scenario 2) were 2.28 (95% CI: 1.21–4.28;  $p=0.011$ ) and 1.36 (95% CI: 0.47–3.89;  $p=0.570$ ), respectively. The OR for interaction is 1.68 (95% CI: 0.49–5.73) meaning that survival benefit due to the volunteer system is more than 1.5 times higher for arrests occurring in the home than for arrests outside the home. The  $p$ -value for interaction is 0.410.

**Ambulance arrival times.** With respect to time of arrival of the first ambulance, a trend was found towards lower survival probability with increasing delay. However, survival in Scenario 2 was higher compared to Scenario 1 within each stratum of ambulance arrival time since notification (Table 1). Importantly, in Scenario 2 the decrease in survival with increasing delay was less substantial than in Scenario 1 (Figure 2(c)).

Strong effects of the system on survival were observed for cases where the first ambulance arrived with slight delay. The relative risk estimate associated with a 7–10 min interval between notification and arrival of the ambulance was 2.63 (95% CI: 1.09–6.35;  $p=0.032$ ). The volunteer system is especially effective when the ambulance arrives with a slight delay (7–10 min) as indicated by the OR for interaction of 1.34. When the delay increases to 11 min or more there is still survival advantage in Scenario 2 compared to Scenario 1, 16% vs 12.9% respectively, but the stratum-specific OR of 1.29 (Table 2) is no longer statistically significant ( $p=0.679$ ).

**Time of the day.** When no volunteers attended (Scenario 1) survival was higher during daytime (21.0%) than at evening/night (11.6%). In the presence of volunteers (Scenario 2) survival percentages were higher than in Scenario 1 and at evening/night survival was even slightly higher than during the day (28.7% and 25.9% respectively), as depicted in Table 1.

The decrease in survival of arrests during evening/night in Scenario 1 combined with the slight increase in survival in Scenario 2 is consistent with a stratum specific OR=3.07 (95% CI: 1.34–7.03;  $p=0.008$ ), favouring Scenario 2. During daytime the contribution to survival was lower with OR=1.32 (95% CI: 0.65–2.67;  $p=0.441$ ). The interaction OR was 2.33 with  $p=0.129$  which indicated that the benefit

of the system during the evening/night is 2.33 times higher compared to the benefit during daytime.

### Adjustment for potential confounders

During the evening or night the distribution of ambulance arrival times differs from that during the day with a higher frequency of longer delays. Distribution of the other effect modifiers (presence of witness and location) may also be different. For this reason, multivariable logistic regression analyses were performed including scenario, all effect modifiers and their terms for interaction with scenario. Age and sex as potential confounders were also added to the model. These analyses gave similar results (not shown).

## Discussion

Recently we reported that survival to hospital discharge in resuscitated out-of-hospital (presumed) cardiac arrest substantially increases by the involvement of citizen responders notified by the ambulance dispatch centre by a text message. In the current study, the hypotheses were tested that the system was especially effective in (a) witnessed OHCA, (b) in the home situation, (c) at longer ambulance delay times and (d) during the evening/night-time.

### Main findings

It was found that the contribution of the system was most pronounced if the OHCA was witnessed (OR=2.25), occurred in the home situation (OR=2.28), when the ambulance arrived with a slight delay i.e. 7–10 min (OR=2.63) and when the OHCA occurred at evening/night (OR=3.07). After adjustment for other effect modifiers, age and gender, results were similar.

**Witnessed and non-witnessed arrests.** One of the most pronounced predictors of survival is OHCA being witnessed.<sup>5</sup> Also, in this study witnessed arrests had a higher survival probability in both scenarios. The attendance of volunteers in case of a witnessed arrest had an additional positive effect on survival. Volunteers apparently effectively shorten the delay time to start CPR before emergency medical services (EMS) arrival. Unwitnessed arrest carries a poor prognosis anyway and volunteers cannot contribute much to improve this.

**Location of the arrest.** Higher survival in OHCA outside the home is related to the higher probability that the collapse is witnessed and that witnesses and/or bystanders will start CPR before the arrival of an ambulance. In this study we found that OHCAs outside the home were witnessed in 81.1% of cases and that CPR was started by a witness or bystander in 84.7%. In OHCAs inside the home, these percentages were 73.9% and 50.0%, respectively. Due to

lower survival probability of OHCA inside the home there is considerable potential for an alert system to contribute to survival. Rapid arrival of volunteers can compensate for the longer delay times until the start of resuscitation. The higher survival gain in the home situation is reflected by the results in this study, where the OR of 2.28 in the home situation is higher than the OR of 1.36 for OHCAs occurring outside the home. These results are promising because the large majority of OHCAs occur in the home, supporting the value of this citizen volunteer system.

**Ambulance arrival times.** Survival is known to be negatively related to longer arrival times of the ambulance.<sup>6,7</sup> Optimal gain in survival by the system can therefore be achieved specifically in settings with more delay until the arrival of healthcare professionals; at short first ambulance arrival times, the ambulance could even arrive before the responders. Importantly, as shown in Figure 2(c), the contribution of the system was typically seen at ambulance arrival times between 6–11 min, which occurred in 44.5% of the cases. Apparently this is the window of opportunity where volunteers contribute mostly to survival. At later arrival times (11 min or later) this benefit and survival decreased, likely due to the overly long time between onset of the arrest and onset of professional care.<sup>8</sup> Although volunteers can provide good quality CPR, early stabilisation of the patient by the EMS is crucial for survival of an OHCA.

**Time of the day.** During daytime, patients in Scenario 2 had a higher probability of survival compared to Scenario 1 (25.9% vs 21.0%). This difference was even greater in the evening/night and amounts to 17.1% (28.7% vs 11.6%, Table 1). These results suggest that gain in survival due to the system is more evident during the evening/night than during the day. There was no difference between the mean number of responders during daytime and evening/night and therefore the gain in survival during night cannot be attributed to better availability and/or preparedness of volunteers during night-time. Instead a lower activation state of the dispatch/ambulance system and/or less availability of ambulances in the evening/night have to be considered, given the decrease in survival rate in Scenario 1, comparing OHCA at evening/night with daytime. This possibility is supported by our data showing that during evening/night the ambulance arrival time >11 min was 34.5% in contrast to 20.6% during the day ( $p<0.001$ ). During the evening/night the system could therefore more effectively compensate for the longer delay time of the ambulance, and contributed to a higher survival rate.

### Comparison with other community responder systems

In different countries several strategies exist to involve citizen volunteers to improve survival of out-of-hospital

circulatory arrest. Comparable to the Dutch alert system is the Mobile Life Service (MLS) in Stockholm, Sweden.<sup>9</sup> In Denmark a volunteer-based network of AEDs (accessible to lay persons) is active where the dispatcher guides bystanders to a close by AED.<sup>10</sup> Also mobile phone applications are used such as the GoodSAM app in the UK, enabling a call to the dispatch centre and alert to nearby registered first aiders. All these systems have in common that they all rely on trained citizen rescuers who are already nearby the OHCA. These trained citizen rescuers can potentially decrease the time between onset of the arrest and time of starting CPR. Every citizen can be a potential rescuer. However, because of the voluntary nature of these systems, it is hard to predict whether volunteers actually will respond to a notification.

Legal issues with regard to the implementation and use of citizen rescuers in case of emergencies differ between countries and should always be explored. To our knowledge up till now no data on their contribution to survival have been published. A previous study in another region in the Netherlands reported that this alert system contributes to earlier defibrillation in sudden cardiac arrest (SCA)<sup>11</sup> but did not report on survival. Although no outcome data were reported, the benefit of the alert system was suggested by a reduced time to defibrillation by citizen responders with AEDs, compared to time to defibrillation by the EMS.

### Limitations

A limitation of the study is the small sample size within specific subgroups that likely resulted in limited power to detect significant interaction. Nevertheless, lack of significance does not indicate absence of interaction and the higher contribution to survival of the alert system in the case of witnessed arrests, in the home, in situations with some delay in arrival of the first ambulance and during the evening/night, is consistent with the a priori hypotheses.

### Conclusion

The contribution of the system to survival of OHCA is most pronounced when OHCA's are witnessed, occur in the home, the ambulance arrives with a delay between 6–11 minutes and the OHCA occurs in the evening or night. Taking only the witnessed arrests into account, the majority of the OHCA's (92.7%) occurred in at least one of the three other conditions (in the home, a delay between 6–11 min or in the evening), indicating that many OHCA victims can benefit from the system.

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### Conflict of interest

The authors declare that there is no conflict of interest.

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