Clinical paper

Mobile phone-based alerting of CPR-trained volunteers simultaneously with the ambulance can reduce the resuscitation-free interval and improve outcome after out-of-hospital cardiac arrest: A German, population-based cohort study

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Abstract

\textbf{Aim:} To test the hypothesis that simultaneous mobile phone-based alerting of CPR-trained volunteers (Mobile-Rescuers) with Emergency Medical Service (EMS) teams leads to better outcomes in out-of-hospital cardiac arrest (OHCA) victims than EMS alerting alone.

\textbf{Methods:} The outcomes of 730 OHCA patients were retrospectively analysed, depending on who initiated CPR: Mobile-Rescuer-initiated-CPR (n = 94), EMS-initiated-CPR (n = 359), lay bystander-initiated-CPR (n = 277). An adjusted analysis of the intervention and their main outcomes (emergency response time, return of spontaneous circulation, hospital discharge rate, neurological outcomes) was performed (Propensity Score Method with patient matching).

\textbf{Results:} Recruited and trained Mobile-Rescuers (n = 740) arrived at the scene in 46% of all triggered alarms. There was a significant difference in response time between Mobile-Rescuers (4 min) and EMS teams (7 min), (p < 0.001). Compared to EMS-initiated-CPR, Mobile-Rescuer-initiated-CPR patients more frequently showed a return of spontaneous circulation, but statistical significance was narrowly missed (p = 0.056). The hospital discharge rate was significantly higher with the Mobile-Rescuer (18%) vs. EMS (7%), (p = 0.049). Good neurological outcomes (Cerebral Performance Categories Score 1 and 2) were seen in 11% of Mobile-Rescuer patients and 4% of EMS patients (p = 0.165). There were no significant differences compared with lay bystander-initiated-CPR.

\textbf{Conclusion:} Simultaneous alerting of nearby CPR-trained volunteers complementary to professional EMS teams can reduce both the response time and resuscitation-free interval and might improve hospital discharge rate and neurological outcomes after OHCA.

\textbf{Keywords:} Prehospital, Cardiac arrest, Resuscitation, First aider, Alerting, Mobile-phone

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Introduction

Out-of-hospital cardiac arrest (OHCA) is a leading cause of death with a low survival rate of 8–10%.1–3 This rate can be increased by early bystander-initiated cardiopulmonary resuscitation (CPR).4–6 However, many patients do not receive any CPR before the arrival of Emergency Medical Service (EMS) personnel at the scene, even if the OHCA is witnessed.7 Reasons for this deficit are a lack of CPR knowledge and skills, a high stress level among lay bystanders, reluctance to practice mouth-to-mouth ventilation and fear of infectious diseases.8 The usual approach to increase rates of lay bystander-initiated-CPR has been to train as many citizens as possible.9 However, this approach is associated with substantial costs and uncertain effects on the rates of lay bystander-initiated-CPR.10 Other approaches are dispatcher-assisted, telephone-guided-CPR (T-CPR) and several “First-Responder” concepts. The principle of T-CPR is that lay bystanders are guided via telephone by experienced dispatchers. First-Responders are typically paramedics, police officers, firefighters, and other trained members of organisations connected with emergency medical care. Training of first responder personnel located closer than medical professionals to the victims is a strategy potentially capable of shortening the resuscitation-free interval.11–13 Modern variants of the “First-Responder” concept are based on use of mobile phone positioning systems and smartphone applications for locating and alerting nearby trained volunteers in cases of OHCA. Although such systems are helpful to significantly increase rates of bystander-initiated-CPR among patients with OHCA,14 little is known about the impact on outcome parameters such as return-of-spontaneous-circulation (ROSC), survival rate, and brain function after cardiac arrest.15

Therefore, we examined the hypothesis that complementary alerting of nearby CPR-trained volunteers (Mobile-Rescuers) using a mobile phone application leads to a higher hospital discharge rate and better neurological outcomes of OHCA victims compared to EMS aid alone without the support of trained volunteers. A comparison was also made with lay bystander-initiated-CPR.

Methods

Study design

In this population-based cohort study, we examined the outcome of OHCA victims depending on who initiated CPR. Data were prospectively collected and retrospectively analysed. The following groups were compared: 1) Mobile-Rescuer-initiated-CPR; 2) EMS-initiated-CPR; 3) lay bystander-initiated-CPR.

Anonymised patient data from the EMS, the rescue coordination centre of the district of Gütersloh (North-Rhine-Westphalia, Germany), and from five regional hospitals were evaluated over a 4-year period (October 2013 to December 2017). The study was approved by the Joint Ethics Committee of the Medical-Association Westfalen-Lippe and the University of Münster (241-I-5-2015).

Setting

The EMS in Gütersloh is operated by the municipal government and implemented by the local fire department. The EMS provides out-of-hospital acute medical care and transport for the entire rural area (total population: 368 000 inhabitants). All emergency calls are routed to a Joint Dispatch Centre. Using decision-support software (Cobra 4 Dispositionsoftware, Computer Aided Dispatch, ISE, Aachen, Germany), the dispatchers decide what resources are needed at the scene of an incident. The first level of out-of-hospital emergency care is provided by ambulances staffed with two Emergency Medical Technicians. In potentially life-threatening situations an Emergency Physician and an additional Emergency Medical Technician are simultaneously sent to the scene with their own vehicle. Treatment of OHCA requires the presence of an Emergency Physician.

Selection of participants

Patient data were considered if they were treated for an OHCA. No cases without CPR attempts were considered, nor those in which the onset of OHCA occurred in the presence of EMS personnel. Traumatic arrests were excluded as they require different interventions, have very poor survival, and possibly a lower rate of bystander-CPR (Fig. 1). Paediatric OHCA were considered, but their number was very low (n=3).

Primary data analysis and risk prediction scores

All data were collected according to the Utstein Guidelines, obtained from standardised electronic patient records. The predefined criterion for the search was the severity of emergencies assessed using the National Advisory Committee for Aeronautics (NACA) scoring system (NACA-category VI: respiratory and/or cardiac arrest).12 To individually predict the outcome after OHCA for each patient, the ROSC-after-cardiac-arrest (RACA) score was determined.13 This tool was chosen because it allows a comparison between predicted and observed resuscitation outcomes and thus a better assessment of the impact of different interventions. All patient records were checked before analysis in terms of completeness and credibility by an experienced Emergency Physician with expertise in the field of large databases. Datasets with missing or implausible data (n=78) or cases that could not be clearly assigned to OHCA (n=19) were excluded.

Mobile-Rescuer-initiated-CPR

Mobile-Rescuers were not complete laypersons and most of them had a medical background. During the study 740 volunteers were recruited and repeatedly trained in CPR. Of these, 60% had a rescue service-associated profession, 11% were firefighters or policemen, 20% medical service staff, 5% nurses, and 4% physicians. The majority (81%) was male. A mobile phone positioning system was used to locate the Mobile-Rescuers who were near a suspected OHCA.14,15 Two Mobile-Rescuers each were alerted if available, complementary to the regular EMS team. This was achieved using an application that connected the Emergency Dispatch Centre with the smartphones of the Mobile-Rescuers via a central web service, navigating the volunteers by car or on foot to the emergency scene. All cases in which the Mobile-Rescuers started with basic-life-support measures (chest compressions, rescue breathing and/or defibrillation with an automated external defibrillator where applicable) were assigned to this study group. In 342 OHCA cases Mobile-Rescuers arrived at the scene (46% of the triggered alarms). Alerting keywords were unconsciousness, breathlessness, seizure, chest pain, collapse, cardiac arrest, and lifeless person.
EMS-initiated-CPR

All OHCA cases in which the CPR was started by EMS personnel (Emergency Physicians or Emergency Medical Technicians) were assigned to this group.

Lay bystander-initiated-CPR

Included were all OHCA cases in which the CPR was started by laypersons that were at the scene but were not part of the organised emergency response system.

In all cases in which CPR was initiated by Mobile-Rescuers or lay bystanders, resuscitation measures were continued by EMS teams after their arrival or interrupted if there was no chance of surviving. The following termination criteria were applied: arrest was not witnessed by EMS personnel, no shock delivered, and no prehospital ROSC. Individual factors such as age, pre-existing diseases, and duration of resuscitation measures have also been included in the decision. Each patient was assigned to only one of the three study groups.

Primary and secondary outcomes

The primary outcome was the hospital discharge rate. Secondary outcome measures were emergency response time, ROSC rate, hospital admission rate, and discharge rate with good neurological outcomes [cerebral performance categories score (CPC) 1 or 2].

Statistics

Descriptive statistical parameters were used and results are presented as mean (SD) or median (interquartile range [range]), if the data were not normally distributed. All data were checked for normality using the Shapiro–Wilk-test. Group comparisons were conducted using Mann–Whitney-rank-sum-test, Ch^2-test, Fisher’s-exact-test, ANOVA, or Kruskal–Wallis-test when appropriate. To reduce the effects of confounding in this observational study an adjusted analysis was performed using the Propensity-Score (PS) Method with patient matching. First, patient characteristics (age, gender, witness status, cause of cardiac arrest, initial rhythm, defibrillation) were used to estimate a PS model, and each patient’s propensity score was calculated. Second, each patient from the Mobile-Rescuer-CPR group (n = 94) was allocated one patient from the EMS-CPR group (1:1 matching based on comparable PS-values). Patients of the lay bystander group were treated in the same way. The Fragility Index was calculated for dichotomous variables (nominal scale) such as ROSC, hospital discharge rate, and neurological outcomes (calculates the number of patients required to lose statistical significance). A p-value < 0.05 was considered statistically significant. Statistical analyses were conducted with Systat 11 for Windows (SigmaStat® 11.0 and SigmaPlot® 11.0, Systat Software, Inc., San Jose, CA, USA).

Results

Demographic findings

Fig. 1 provides an overview of the total number of OHCA and the cases included and excluded for analysis as well as the study groups compared. Demographic data of the patients, prehospital characteristics, and ambulance response time data are summarised for all groups in Table 1.

Prediction of individual prognosis

Patients who underwent EMS-initiated-CPR had a significantly lower RACA score (34% [24–43 [10–76]) compared to lay bystander-initiated-CPR (46% [30–61 [19–88]}; p < 0.001). No difference was seen between EMS-initiated-CPR and Mobile-Rescuer-initiated-CPR (33% [23–51 [10–82]); p = 0.421). Sixty-eight percent of all OHCA
victims were male and 32% were female. A shockable rhythm existed in only one-quarter of all OHCA. This proportion was even lower in patients who underwent EMS-initiated-CPR (not significant, p = 0.279). The median ambulance response time for the entire cohort was 7 (5–11 [3–19]) min. In 76% of all cases, the first ambulance vehicle arrived at the scene within 8 min after raising the alarm. There were no significant group differences with regard to age, gender distribution, initial rhythm, and ambulance response time. Likewise, no significant group differences were seen regarding the aetiology of hypoxia (EMS group 10%, lay bystander group 8%, Mobile-Rescuer group 5%), and the aetiology of intoxication (EMS group 2%, lay bystander group 1%, Mobile-Rescuer group 4%). The rate of witnessed OHCA was significantly higher in patients who underwent lay bystander-initiated-CPR than EMS-initiated-CPR (p < 0.021). No significant difference in witness status was found between EMS-initiated-CPR and Mobile-Rescuer-initiated-CPR (p = 0.529).

**Outcome data**

A summary of prehospital interventions is shown in Table 2. Parameters describing the early period after cardiac arrest are presented in Table 3. A non-adjusted comparison between groups showed significant differences in terms of hospital discharge rate and neurological outcome (Fig. 2). Both values were highest in patients who underwent Mobile-Rescuer-initiated-CPR and lowest in patients who underwent EMS-initiated-CPR (hospital discharge rate: p = 0.029; CPC 1 or 2 at discharge: p = 0.038; Fragility Index: 1).

No significant differences existed compared with lay bystander-initiated-CPR. Results of the adjusted analysis comparing the Mobile-Rescuer group (n = 94) and EMS group (n = 94) in terms of the main outcome parameters are shown in Table 4. In this regard, no significant differences between Mobile-Rescuer-initiated-CPR and lay bystander-initiated CPR were seen.

**Discussion**

This is the first study that shows a positive effect of using a mobile phone-based alerting system for voluntary first aiders on the outcome of OHCA victims. Our main finding was that simultaneous alerting of nearby CPR-trained volunteers complementary to professional EMS teams can reduce both response time and the resuscitation-free interval and improve hospital discharge rate and neurological outcomes after OHCA.

**Table 1 - Demographic data and prehospital characteristics of OHCA patients depending on who started the CPR.**

<table>
<thead>
<tr>
<th></th>
<th>CPR started by EMS personnel (n = 359)</th>
<th>CPR started by Lay bystanders (n = 277)</th>
<th>CPR started by Mobile-Rescuers (n = 94)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years); Median (IQR[Range])</td>
<td>73 (65–87 [0–99])</td>
<td>70 (62–82 [0–97])</td>
<td>75 (68–83 [0–93])</td>
</tr>
<tr>
<td>Gender (male/female); n (%)</td>
<td>234/125 (65%/35%)</td>
<td>198/79 (71%/29%)</td>
<td>64/30 (68%/32%)</td>
</tr>
<tr>
<td>Witness status; n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Witnessed arrest:</td>
<td>161/359 (45%)</td>
<td>181/277 (65%)</td>
<td>45/94 (48%)</td>
</tr>
<tr>
<td>Unwitnessed arrest:</td>
<td>198/359 (55%)</td>
<td>96/277 (35%)</td>
<td>49/94 (52%)</td>
</tr>
<tr>
<td>Cause of cardiac arrest; n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac:</td>
<td>185/359 (52%)</td>
<td>174/277 (63%)</td>
<td>53/94 (56%)</td>
</tr>
<tr>
<td>Noncardiac:</td>
<td>174/359 (48%)</td>
<td>103/277 (37%)</td>
<td>41/94 (44%)</td>
</tr>
<tr>
<td>Location of cardiac arrest; n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At home:</td>
<td>263/359 (73%)</td>
<td>208/277 (75%)</td>
<td>69/94 (73%)</td>
</tr>
<tr>
<td>Other location:</td>
<td>96/359 (27%)</td>
<td>69/277 (25%)</td>
<td>25/94 (27%)</td>
</tr>
<tr>
<td>Ambulance response time (min); Median (IQR[Range])</td>
<td>8 (6–11 [3–18])</td>
<td>7 (5–10 [4–16])</td>
<td>7 (6–9 [3–14])</td>
</tr>
<tr>
<td>Initial rhythm; n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VT/VF:</td>
<td>74/359 (21%)</td>
<td>76/277 (28%)</td>
<td>24/94 (26%)</td>
</tr>
<tr>
<td>Asystole:</td>
<td>230/359 (64%)</td>
<td>162/277 (58%)</td>
<td>59/94 (63%)</td>
</tr>
<tr>
<td>PEA:</td>
<td>55/359 (15%)</td>
<td>39/277 (14%)</td>
<td>11/94 (11%)</td>
</tr>
</tbody>
</table>

Ambulance response time = alarm raised to arrival of EMS team; CPR = cardiopulmonary resuscitation; EMS = emergency medical service; IQR, interquartile range, OHCA = out-of-hospital cardiac arrest; PEA = pulseless electrical activity; VF = ventricular fibrillation; VT = ventricular tachycardia.

**Table 2 - Preclinical therapeutic interventions.**

<table>
<thead>
<tr>
<th></th>
<th>CPR started by EMS personnel (n = 359)</th>
<th>CPR started by Lay bystanders (n = 277)</th>
<th>CPR started by Mobile-Rescuers (n = 94)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defibrillation; n (%)</td>
<td>79/359 (22%)</td>
<td>80/277 (29%)</td>
<td>24/94 (25%)</td>
</tr>
<tr>
<td>Endotracheal intubation; n (%)</td>
<td>156/359 (43%)</td>
<td>116/277 (42%)</td>
<td>40/94 (43%)</td>
</tr>
<tr>
<td>Supraglottic airway; n (%)</td>
<td>110/359 (31%)</td>
<td>72/277 (26%)</td>
<td>30/94 (32%)</td>
</tr>
<tr>
<td>Adrenaline; n (%)</td>
<td>196/359 (55%)</td>
<td>147/277 (53%)</td>
<td>51/94 (54%)</td>
</tr>
<tr>
<td>Amiodarone; n (%)</td>
<td>69/359 (19%)</td>
<td>65/277 (23%)</td>
<td>24/94 (25%)</td>
</tr>
</tbody>
</table>

CPR = cardiopulmonary resuscitation; EMS = emergency medical service.
Table 3 – Return of spontaneous circulation, hospital admission, and clinical outcomes (non-adjusted comparison between groups).

<table>
<thead>
<tr>
<th></th>
<th>CPR started by EMS personnel (n = 359)</th>
<th>CPR started by Lay bystanders (n = 277)</th>
<th>CPR started by Mobile-Rescuers (n = 94)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROSC ever; n (%)</td>
<td>154/359 (43%)</td>
<td>120/277 (43%)</td>
<td>43/94 (46%)</td>
</tr>
<tr>
<td>ROSC never; n (%)</td>
<td>205/359 (57%)</td>
<td>157/277 (57%)</td>
<td>51/94 (54%)</td>
</tr>
<tr>
<td>ROSC at hospital admission; n (%)</td>
<td>133/359 (37%)</td>
<td>108/277 (39%)</td>
<td>42/94 (45%)</td>
</tr>
<tr>
<td>Hospital admission under ongoing CPR; n (%)</td>
<td>29/359 (8%)</td>
<td>22/277 (8%)</td>
<td>7/94 (7%)</td>
</tr>
<tr>
<td>Hospital admission rate total; n (%)</td>
<td>165/359 (48%)</td>
<td>127/277 (46%)</td>
<td>49/94 (51%)</td>
</tr>
<tr>
<td>Hospital discharge rate; n (%)</td>
<td>32/359 (9%)</td>
<td>42/277 (15%)</td>
<td>17/94 (18%)</td>
</tr>
<tr>
<td>Good neurological outcome; n (%)</td>
<td>18/359 (5%)</td>
<td>28/277 (10%)</td>
<td>10/94 (11%)</td>
</tr>
</tbody>
</table>

CPR = cardiopulmonary resuscitation; EMS = emergency medical service; ROSC = return of spontaneous circulation. Cerebral performance categories score (CPC) 1 and 2 are summarised as good neurological outcome (CPC 1: good cerebral performance, CPC 2: moderate cerebral disability).

Fig. 2 – Hospital discharge rate and neurological outcome after out-of-hospital cardiac arrest (OHCA): results of a non-adjusted analysis.

(*) Good neurological outcomes: EMS-initiated-CPR vs. Mobile-Rescuer-initiated-CPR (p = 0.049). (**) hospital discharge rate: EMS-initiated-CPR vs. Mobile-Rescuer-initiated-CPR (p = 0.027).

EMS, Emergency Medical Service; CPC, Cerebral performance categories score where CPC 1 = good cerebral performance, CPC 2 = moderate cerebral disability, CPC 3 = severe cerebral disability, CPC 4 = coma or vegetative state, CPC 5 = brain death; CPC 1 and 2 were summarised as good neurological outcomes.

**Prediction of ROSC**

Several studies have identified key predictors of OHCA survival.19–21 In a meta-analysis, Sasson et al. extracted data from 79 studies.4 They showed that survival to hospital discharge was more likely if the collapse was witnessed by bystanders or even more by EMS personnel, in patients who received bystander CPR, when ventricular fibrillation or ventricular tachycardia was the initial rhythm, and when ROSC was achieved. In 2011, Gräsner et al. published a score to predict the initial resuscitation outcome – the RACA (ROSC after cardiac arrest) score.13 This is considered a simple tool enabling comparison between predicted and observed ROSC rates, based on readily-available variables after OHCA.22 The RACA score may contribute to preclinical quality assessment and help analyse the effects of different therapeutic strategies.13,22,23 In EMS teams operating at a high-quality level, the observed ROSC rate may be higher than the predicted ROSC rate. Contrarily, where the observed ROSC rate is lower than the predicted ROSC rate, further analyses of the EMS-structure and process quality may be useful to identify reasons for that low performance.25 In our study, we saw a striking difference in patients who underwent Mobile-Rescuer-initiated-CPR. The predicted ROSC rate in this group was about 30%, as low as in patients who underwent EMS-initiated-CPR, yet the observed ROSC rate, and particularly the ROSC rate at hospital admission, was 45% - the highest of all study groups. This contrast is probably caused by the fact that in all cases where no resuscitation measures were taken by lay bystanders, the RACA score value was reduced, regardless of the fact that CPR was shortly afterwards initiated by Mobile-Rescuers. For this reason, the RACA score should also consider the activity of Mobile-Rescuers. In general, the results of our study suggest that the performance of the EMS and the process quality in Gütersloh are above average. The pooled ROSC rate on arrival at hospital was 39% and the survival rate to hospital discharge was 13%. In comparison, a European multinational prospective study including data on 10,682 confirmed OHCA showed a lower ROSC rate at hospital admission of 25% and a lower hospital discharge rate of 10.3%.24

**Bystander-CPR**

Bystander-CPR for witnessed OHCA is believed to strongly influence survival to hospital discharge.26 Hasselqvist-Ax et al. analysed more than 30,000 witnessed OHCA in Sweden. They showed that CPR performed before EMS arrival was associated with a 30-day survival rate after an OHCA that was more than twice as high as that associated with no CPR before EMS arrival.15 This finding is consistent with those of other studies.26,27 Other authors even demonstrated better neurological outcomes associated with bystander-initiated resuscitation.28 The most likely reason for the increased survival rate and the better neurological outcomes after OHCA related to bystander...
activity is that early CPR maintains a certain degree of circulation, which may prevent ventricular fibrillation from deteriorating to asystole before EMS arrives. This thesis is confirmed by our results, as we observed higher rates of shockable rhythms in patients who underwent lay bystander- and Mobile-Rescuer-initiated CPR compared to resuscitations started by EMS. Despite these known advantages, the rate of lay bystander-CPR remains too low. Nevertheless, there are great differences between countries in this respect.14,15,28–30

**Mobile phone-based alerting of volunteers**

Using mobile phone positioning systems, people who have smartphones can be located and sent to assist patients with suspected OHCA.31 This approach has been implemented in several countries.8,10,14,15,32–36 However, literature that puts the use of such systems in relation to the outcome of OHCA victims is scarce.10 The most important study which deals with this issue was published in 2015 by Ringh et al.11 These authors recruited 9828 lay volunteers in a metropolitan environment. Around half were trained in CPR. The mobile phone positioning system was activated at the dispatch centre in parallel with the ambulance dispatch when an OHCA was suspected. All volunteers within a radius of 500 m from the patient received a computer-generated telephone call and a text message with information on the patient’s location. The rate of lay bystander-initiated-CPR was increased by 14% using this intervention. No effect was shown in terms of ROSC rate and 30-day survival. In contrast to the Ringh study, the volunteers in our study were not complete laypersons and most of them had a medical background. As this could have an impact on motivation and quality of resuscitation measures, we differentiated the data for lay bystander-initiated-CPR and Mobile-Rescuer-initiated-CPR and evaluated these separately. In almost half of all triggered alarms, Mobile-Rescuers arrived at the scene. This result indicates a high level of commitment among volunteers in our project. Other authors reported a much lower response rate of only 23%.35 Despite their short response time, Mobile-Rescuers were first at the scene only in one-third of all cases. In most other cases, CPR had already been initiated by lay bystanders when Mobile-Rescuers arrived. In less than 10 per cent of the 342 OHCA cases where Mobile-Rescuers arrived at the scene, EMS personnel was there before. This implies that these OHCA victims had benefited from the activity of Mobile-Rescuers where ambulance response time was long and patients did not receive any CPR by lay bystanders before the arrival of EMS.

**Limitations**

As the present study included only cases with complete data sets for all required variables, a selection bias cannot be ruled out. Furthermore, the duration of the resuscitation measures was not included in the analysis although it may have impact on outcome parameters such as ROSC, survival rate, and brain function after cardiac arrest. In addition, early use of defibrillators by lay bystanders is positively associated with an increased survival rate.37 Whether defibrillation was performed by lay bystanders or Mobile-Rescuers respectively, and/or later by EMS personnel after arrival of the ambulance, has not been recorded in our study. The same applies to the question in how many cases had mouth-to-mouth ventilation already been performed by lay bystanders in addition to to chest compression, or whether sufficient airway management had only been started by EMS staff. The lack of this information makes it more difficult to clearly define the impact of each group involved in the treatment of OHCA patients. In addition, a Fragility Index of 1 indicates unstable results in terms of the primary outcome hospital discharge.

**Future perspectives**

Although mobile phone positioning and alerting systems have proved to be an effective tool for shortening the response time, it should be emphasised that it can only be a complementary resource in the context of emergency care. The Mobile-Rescuer concept should not be considered an opportunity to close supply gaps and compensate a lack of investment, but as an additional component of a greater rescue network.

**Conclusion**

Simultaneous alerting of nearby CPR-trained volunteers complementary to professional EMS teams can reduce both response time and
resuscitation-free interval and might improve hospital discharge rate and neurological outcomes after OHCA. Whether Mobile-Rescuer-initiated-CPR is superior to lay bystander-initiated-CPR due to a more qualified execution of resuscitation measures is an open question that should be answered in future studies.

Conflicts of interest statement

We declare that there is no conflict of interest regarding any financial or personal relationships with the manufacturers or with any other people or organisations that could inappropriately influence or bias our work.

Acknowledgement

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REFERENCES