ORIGINAL ARTICLE

Mobile-Phone Dispatch of Laypersons for CPR in Out-of-Hospital Cardiac Arrest

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ABSTRACT

BACKGROUND

Cardiopulmonary resuscitation (CPR) performed by bystanders is associated with increased survival rates among persons with out-of-hospital cardiac arrest. We investigated whether rates of bystander-initiated CPR could be increased with the use of a mobile-phone positioning system that could instantly locate mobile-phone users and dispatch lay volunteers who were trained in CPR to a patient nearby with out-of-hospital cardiac arrest.

METHODS

We conducted a blinded, randomized, controlled trial in Stockholm from April 2012 through December 2013. A mobile-phone positioning system that was activated when ambulance, fire, and police services were dispatched was used to locate trained volunteers who were within 500 m of patients with out-of-hospital cardiac arrest; volunteers were then dispatched to the patients (the intervention group) or not dispatched to them (the control group). The primary outcome was bystander-initiated CPR before the arrival of ambulance, fire, and police services.

RESULTS

A total of 5989 lay volunteers who were trained in CPR were recruited initially, and overall 9828 were recruited during the study. The mobile-phone positioning system was activated in 667 out-of-hospital cardiac arrests: 46% (306 patients) in the intervention group and 54% (361 patients) in the control group. The rate of bystander-initiated CPR was 62% (188 of 305 patients) in the intervention group and 48% (172 of 360 patients) in the control group (absolute difference for intervention vs. control, 14 percentage points; 95% confidence interval, 6 to 21; P<0.001).

CONCLUSIONS

A mobile-phone positioning system to dispatch lay volunteers who were trained in CPR was associated with significantly increased rates of bystander-initiated CPR among persons with out-of-hospital cardiac arrest. (Funded by the Swedish Heart–Lung Foundation and Stockholm County; ClinicalTrials.gov number, NCT01789554.)

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Bystander-initiated cardiopulmonary resuscitation (CPR) before the arrival of emergency-medical-services (EMS) personnel is associated with a rate of survival among patients with out-of-hospital cardiac arrest that is up to three times as high as the rate among patients who do not receive such assistance.[1,2] Low rates of bystander-initiated CPR are a major obstacle to improved survival rates.[3]

The usual approach to increase rates of bystander-initiated CPR has been to train as much of the public as possible.[4] However, this approach is associated with substantial costs and uncertain effects on rates of bystander-initiated CPR.[5] With the use of a mobile-phone positioning system, persons who have mobile phones can be located[6] and sent to assist patients with suspected out-of-hospital cardiac arrest; this approach has been reported in prior pilot and simulation studies.[7,8]

We hypothesized that the use of a mobile-phone positioning system to dispatch lay responders who are trained in CPR to assist patients with suspected out-of-hospital cardiac arrest would increase the proportion of cases in which CPR was performed by trained bystanders.

METHODS

STUDY DESIGN AND SETTING

The study was a community-based, blinded, randomized, controlled trial that was conducted in Stockholm County from April 1, 2012, through December 1, 2013. Stockholm County covers 6519 km^2 and has a population of more than 2 million.[9]

At the time of the study, the incidence of out-of-hospital cardiac arrests that were treated by EMS personnel was 46 per 100,000 persons. One dispatch center received all emergency calls; 58 ambulances were available for dispatch from 7 a.m. to 9 p.m. (which was considered to be daytime), and 38 ambulances were available at night. In addition, 47 fire vehicles and 110 police vehicles were available at all times for dual dispatch to assist patients with suspected out-of-hospital cardiac arrest.

STUDY OVERSIGHT

All the investigators (who are listed in the Supplementary Appendix, available with the full text of this article at NEJM.org) vouch for the accuracy and completeness of the data and adherence to the study protocol, which is available at NEJM.org. The ethics board at the Karolinska Institutet in Stockholm approved the study and waived the requirement for informed consent. There was no commercial support for this study.

MOBILE-PHONE POSITIONING SYSTEM

A mobile-phone positioning system can locate individual mobile phones geographically.[10] We developed a mobile-phone positioning system that was tailored for the present study (Fig. 1) (see the Supplementary Appendix).

RECRUITMENT OF LAY VOLUNTEERS

Lay volunteers who were trained in CPR were recruited through advertising campaigns and at CPR training courses. We called these volunteers “short-message-service lifesavers.” Registration for participation in the mobile-phone positioning system was Web-based[11] (details are provided in the Supplementary Appendix).

DISPATCH OF LAY VOLUNTEERS

The sources of all emergency calls to the dispatch center in Stockholm are geographically located and are handled by dispatchers according to a structured medical protocol. When an out-of-hospital cardiac arrest is suspected (the patient is unconscious and is not breathing normally), several actions are undertaken, including the dispatch of an ambulance and first responders (i.e., fire and police vehicles) and, if needed, the provision over the telephone of instructions on how to perform CPR.

In this study, after consulting the medical protocol, dispatchers who suspected that a patient had cardiac arrest activated the mobile-phone positioning system. Data about the type of emergency and geographic coordinates were exported from the dispatch-center computer system to the mobile-phone positioning system. The location of the patient with suspected out-of-hospital cardiac arrest was compared with the current locations of trained lay volunteers. All such 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 (Fig. S1 in the Supplementary Appendix). A Web link to a map showing the location was also sent to the volunteer.

RANDOMIZATION PROCEDURE

For practical reasons, the mobile-phone positioning system was active between 6 a.m. and 11 p.m. After the system was activated by dispatchers, pa-

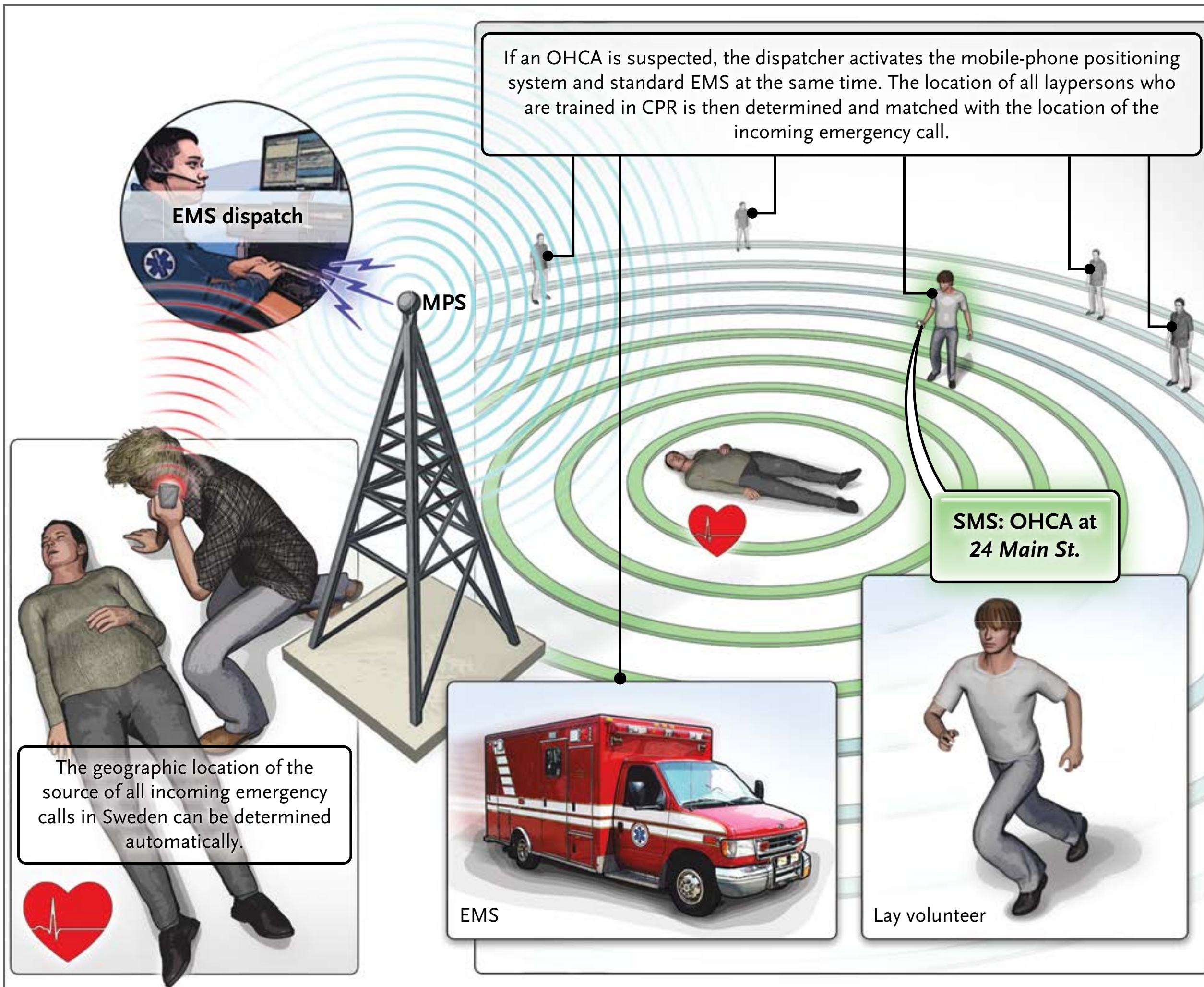

Figure 1. Mobile-Phone Positioning System.

Dispatchers were instructed to activate the mobile-phone positioning system (MPS) in cases of suspected out-of-hospital cardiac arrest (OHCA). Lay volunteers who were trained in cardiopulmonary resuscitation (CPR) and who were located within a 500-m radius of patients who were randomly assigned to the intervention group were contacted by means of short-message-service (SMS) messaging and a computer-generated voice call to their mobile phones. Patients with a cardiac arrest that was witnessed by emergency-medical-services (EMS) personnel and patients in whom resuscitation was not attempted by the EMS personnel (because of ethical reasons or obvious signs of death) were excluded from the final analysis.

tients were randomly assigned in a 1:1 ratio to one of the two study groups by means of a computerized randomization system. Random numbers were automatically generated within the mobile-phone positioning system with the use of a modified standard function in Microsoft.NET Framework software, version 4.0.[12]

If a patient with suspected out-of-hospital cardiac arrest was randomly assigned to the intervention group, lay volunteers were located. If a volunteer was located within 500 m of the patient, the volunteer was contacted automatically by means of short-message-service messaging (text messaging) and computer-generated telephone calls. If a patient was randomly assigned to the control group, lay volunteers who were trained in CPR were located, but no final contact was made by means of text messaging or telephone calls. The dispatcher was unaware of the study-group assignments, and all the investigators were unaware of the assignments until the final analysis was completed and the randomization code was revealed.

PATIENTS

The inclusion criterion for randomization was suspected out-of-hospital cardiac arrest. The exclusion criteria were the following: suspected out-of-hospital cardiac arrest in a patient younger than 8 years of age, a hazardous environment, and out-of-hospital cardiac arrest caused by drowning, trauma, intoxication, or suicide.

For data analysis, all out-of-hospital cardiac arrests that were treated by EMS personnel in which the mobile-phone positioning system service was activated were included. If no lay volunteers who were trained in CPR were present within 500 m of the patient, the case was not excluded from the final analysis. All out-of-hospital cardiac arrests that were not treated by EMS personnel and cardiac arrests that were witnessed (seen or heard) by EMS personnel were excluded.

PRIMARY AND SECONDARY OUTCOMES

The primary outcome was the rate of bystander-initiated CPR before the arrival of an ambulance or first responders. Cases in which CPR was administered only with the help of instructions for how to perform CPR given over the telephone (i.e., not by trained volunteers) were not considered to be bystander-initiated CPR.

Secondary outcomes were bystander-initiated CPR, including CPR that was given only with the help of instructions given over the telephone, findings of ventricular fibrillation or ventricular tachycardia at the first electrocardiographic assessment, return of spontaneous circulation, and 30-day survival.

Primary and secondary outcome data were obtained from ambulance and first-responder records, the Swedish Cardiac Arrest Registry (which included 30-day survival data), and survey data from lay volunteers who were trained in CPR and were dispatched to assist patients with cardiac arrest.

STATISTICAL ANALYSIS

On the basis of results of a pilot study and reported rates of CPR in Stockholm County, we hypothesized that there would be a 25% increase in the rate of bystander-initiated CPR, or an increase of 12.5 percentage points (from 50.0% to 62.5%), among patients with out-of-hospital cardiac arrest who were assigned to the intervention group.[7] We estimated that a total sample of 492 patients would be needed to provide a statistical power of 80% to detect this increase, at a two-sided significance level of 5%. To confirm that the sample size was adequate and to permit a safety analysis, a prespecified interim analysis was performed after the inclusion of 200 patients. Power calculations were performed with the use of SPSS Sample Power 2.0 software (SPSS).

The chi-square test was used to assess the between-group differences both in the proportion of bystander-initiated CPR (i.e., the primary outcome) and in the secondary outcomes. We present the estimated between-group differences in proportions and 95% confidence intervals, which were calculated by means of the asymptotic method without continuity correction.[13]

Logistic regression was used to study the associations between bystander-initiated CPR and the intervention and each of the other eight possible confounding factors (the presence of ventricular fibrillation, the presence of ventricular tachycardia, the cause of cardiac arrest, whether the cardiac arrest had been witnessed, the location of the cardiac arrest, the sex of the patient, the response time, and the patient's age) (Table S1 in the Supplementary Appendix). Logistic regression was also used to determine the corresponding results after adjustment for these factors. The model strategy was as follows. First, we studied the association between bystander-initiated CPR and each of the factors one at a time. Second, we estimated an adjusted model with all the factors to study the effect of the intervention adjusted for possible confounders. Third, to see whether the effect of the intervention differed between the two groups after adjustment for the possible confounders, we tested possible two-way interactions between the intervention and each of the other factors with the use of the Wald test. The results are presented as odds ratios and corresponding 95% confidence intervals.

The analysis was performed with the use of IBM SPSS software, version 22, and VassarStats (http://vassarstats.net/prop2_ind.htm). A two-sided P value of less than 0.05 was considered to indicate statistical significance. The Hosmer–Lemeshow goodness-of-fit test was used to assess the adjusted models, with P values above 0.05 consid-

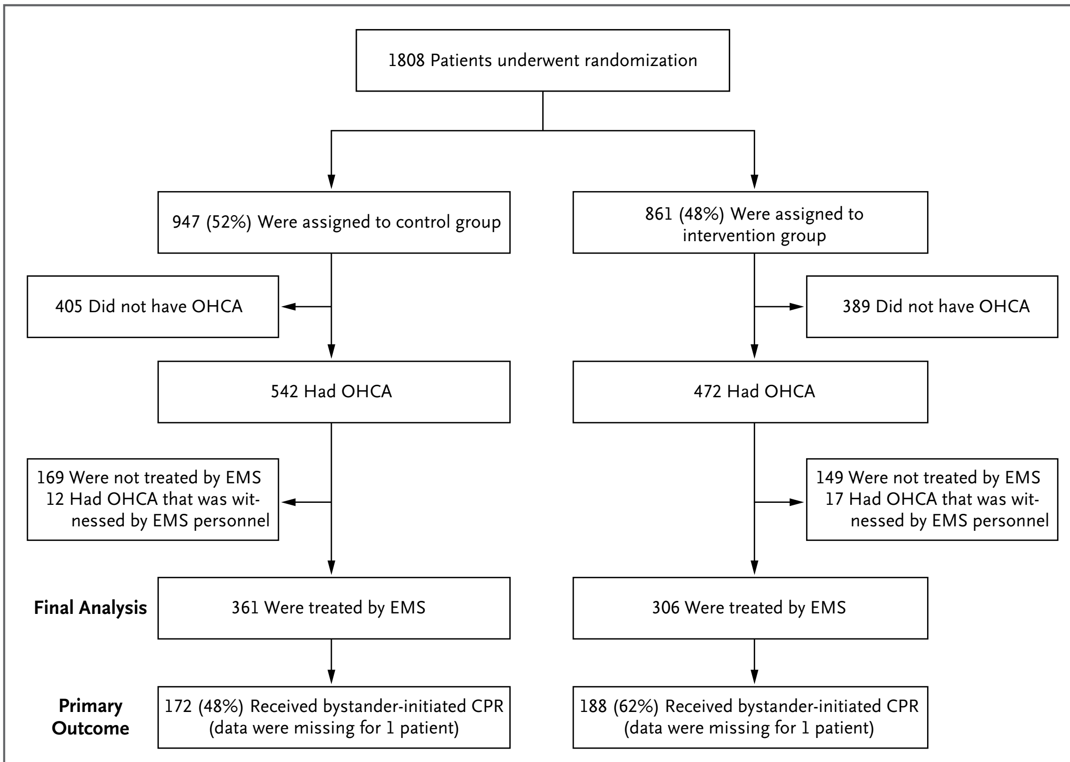

Figure 2. Randomization and Treatment of Patients after Activation of the Mobile-Phone Positioning System by Emergency Dispatchers.

ered to indicate an acceptable fit. No adjustment was made for multiple testing.

RESULTS

LAY VOLUNTEERS

A total of 5989 lay volunteers who were trained in CPR were recruited at the start of the study, and 9828 were recruited by the end of the study. Among the lay volunteers who were recruited initially, 48% (2898) were men; the mean age was 40 years.

PATIENTS

Figure 2 shows the assignment of patients to the intervention group or the control group. The mobile-phone positioning system was activated in 1808 cases of suspected out-of-hospital cardiac arrest. Patients who did not receive treatment from EMS personnel were excluded, as were patients with cardiac arrest that was witnessed by EMS personnel. In the final outcome analysis, 667 patients with out-of-hospital cardiac arrests were included: 46% (306 patients) in the intervention group and 54% (361 patients) in the control group.

Table 1 shows the baseline characteristics of all the patients with out-of-hospital cardiac arrest who were included in the outcome analysis. There were no significant differences between the two groups.

OUTCOMES

As shown in Table 2, there was a between-group difference of 13.9 percentage points (95% confidence interval [CI], 6.2 to 21.2; P<0.001) in the primary outcome: 61.6% of the patients in the intervention group (188 of 305 patients) received bystander-initiated CPR, as compared with 47.8% of the patients in the control group (172 of 360 patients). There was also a significant difference (9.5 percentage points; 95% CI, 2.0 to 16.9; P=0.01) if cases in which instructions for how to perform CPR were provided over the telephone were counted as bystander-initiated CPR; with inclusion of these cases, 64.3% of patients in the intervention group received bystander-initiated CPR as compared with 54.7% of patients in the

Table 1. Baseline Characteristics of 667 Patients with Out-of-Hospital Cardiac Arrest Treated by EMS Personnel, According to Treatment Group.*

Characteristic	Intervention (N=306)	Control (N=361)
Age — yr		
Median	71.0	73.5
Interquartile range	62.5–81.3	61.8–83.3
Male sex — no. of patients/total no. (%)	213/302 (70.5)	225/351 (64.1)
Location of cardiac arrest — no. of patients/total no. (%)		
Home	209/303 (69.0)	251/353 (71.1)
Not at home	94/303 (31.0)	102/353 (28.9)
Underlying cause of cardiac arrest — no. of patients/total no. (%)		
Cardiac	246/303 (81.2)	282/352 (80.1)
Noncardiac	57/303 (18.8)	70/352 (19.9)
Cardiac arrest witnessed by bystanders — no. of cardiac arrests/total no. (%)		
Yes	165/290 (56.9)	186/323 (57.6)
No	125/290 (43.1)	137/323 (42.4)
CPR performed with telephone instructions — no. of patients/total no. (%)	10/249 (4.0)	23/278 (8.3)
Interval between call to and first arrival of EMS personnel — min		
Median	8.3	8.2
Interquartile range	5.4–12.8	5.5–11.9
Bystander-initiated CPR — no. of patients (%)		
Not including CPR performed with telephone instructions	188 (61.6)	172 (47.8)
Including CPR performed with telephone instructions†	196 (64.3)	197 (54.7)

* Cardiac arrests that were witnessed by EMS personnel were not included in the analyses. There were no significant differences between the groups. CPR denotes cardiopulmonary resuscitation, and EMS emergency medical services.
† Some cases of bystander-initiated CPR were performed with telephone instructions and by a trained volunteer.

Table 2. Primary and Secondary Outcomes.*

Outcome	Intervention	Control	Difference (95% CI)	P Value
	no. of patients/total no. (%)		*percentage points*	
Primary outcome: bystander-initiated CPR	188/305 (61.6)	172/360 (47.8)	13.9 (6.2 to 21.2)	<0.001
Secondary outcome				
30-day survival	32/286 (11.2)	28/326 (8.6)	2.6 (−2.1 to 7.8)	0.28
Return of spontaneous circulation	90/306 (29.4)	105/361 (29.1)	0.3 (−6.5 to 7.3)	0.93
Shockable rhythm: ventricular fibrillation or ventricular tachycardia	58/301(19.3)	60/347 (17.3)	2.0 (−4.0 to 8.0)	0.52
Bystander-initiated CPR including CPR performed with telephone instructions	196/305 (64.3)	197/360 (54.7)	9.5 (2.0 to 16.9)	0.01

* CI denotes confidence interval.

control group. No significant between-group differences were seen in other secondary outcomes (return of spontaneous circulation, initial cardiac rhythm, and 30-day survival).

In the unadjusted analysis (Table S1 in the Supplementary Appendix), the odds ratio for CPR before the arrival of an ambulance or first responders was 1.8 (95% CI, 1.3 to 2.6) among patients

Table 3. Response of Volunteers Who Were Trained in CPR, According to Survey Data.*

Variable	Intervention (N=306)†	Control (N=361)†	All Suspected Out-of-Hospital Cardiac Arrests (N=861)
Cases of out-of-hospital cardiac arrest in which volunteers were located within 500 m — no. (%)			
No volunteers	57 (19)	83 (23)	124 (14)
1–3 volunteers	86 (28)	135 (37)	236 (27)
4–9 volunteers	86 (28)	89 (25)	289 (34)
>10 volunteers	77 (25)	54 (15)	212 (25)
Volunteer action — proportion of cases (%)			
1 or more volunteers responded to SMS or voice alarms	199 (65)	NA	595 (69)
Volunteers reached scene	180 (59)	NA	520 (60)
Volunteers arrived at scene before EMS personnel and first responders	70 (23)	NA	202 (23)
Volunteers started CPR	40 (13)	NA	NA

* Patients who did not receive treatment from EMS personnel were excluded from the final outcome analysis, as were patients with cardiac arrest that was witnessed by EMS personnel. NA denotes not applicable, and SMS short message service.

† Patients who did not receive treatment from EMS personnel were excluded from the final outcome analysis, as were patients with cardiac arrest that was witnessed by EMS personnel.

assigned to intervention. When adjusted for the covariates listed in the Statistical Analysis section, the odds ratio for the likelihood of bystander-initiated CPR was 1.7 (95% CI, 1.2 to 2.5).

There was no significant difference in the intervention effect according to prespecified subgroups except in the subgroup of patients with shockable versus those with nonshockable rhythm (P=0.03 for the interaction between shockable and nonshockable rhythm) (Table S2 in the Supplementary Appendix).

RESULTS OF SURVEY DATA

According to survey data obtained from lay volunteers, one or more lay volunteers who were trained in CPR were located within 500 m of the patient in 81% of the cases of cardiac arrest (249 of 306 patients) (Table 3). In 199 out-of-hospital cardiac arrests (65%), one or more lay volunteers who were trained in CPR tried to reach the patient; in 70 cardiac arrests (23%), the trained volunteer or volunteers reached the patient before the arrival of the EMS personnel or first responders. In 40 cases (13%), one or more trained volunteers stated that they initiated CPR before anyone else arrived.

OUT-OF-HOSPITAL CARDIAC ARRESTS THAT WERE NOT RANDOMLY ASSIGNED

The mobile-phone positioning system was not activated by dispatchers in 925 out-of-hospital cardiac arrests that were treated by EMS personnel, and subsequently these patients did not undergo randomization (Fig. 3). When cardiac arrests that were witnessed by EMS personnel were excluded, 736 patients with cardiac arrest were not included in the final analysis; 515 of these cardiac arrests occurred during the daytime. Review of the medical protocol used by dispatchers revealed that in 237 of these patients, the dispatcher suspected an out-of-hospital cardiac arrest but did not activate the mobile-phone positioning system. These 237 patients comprised 26% of all eligible patients. Baseline characteristics of the 736 patients and events that were not assigned to the intervention or control group are provided in Table S3 in the Supplementary Appendix.

DISCUSSION

This randomized, controlled trial evaluated a mobile-phone positioning system for locating and recruiting lay responders who were trained in CPR

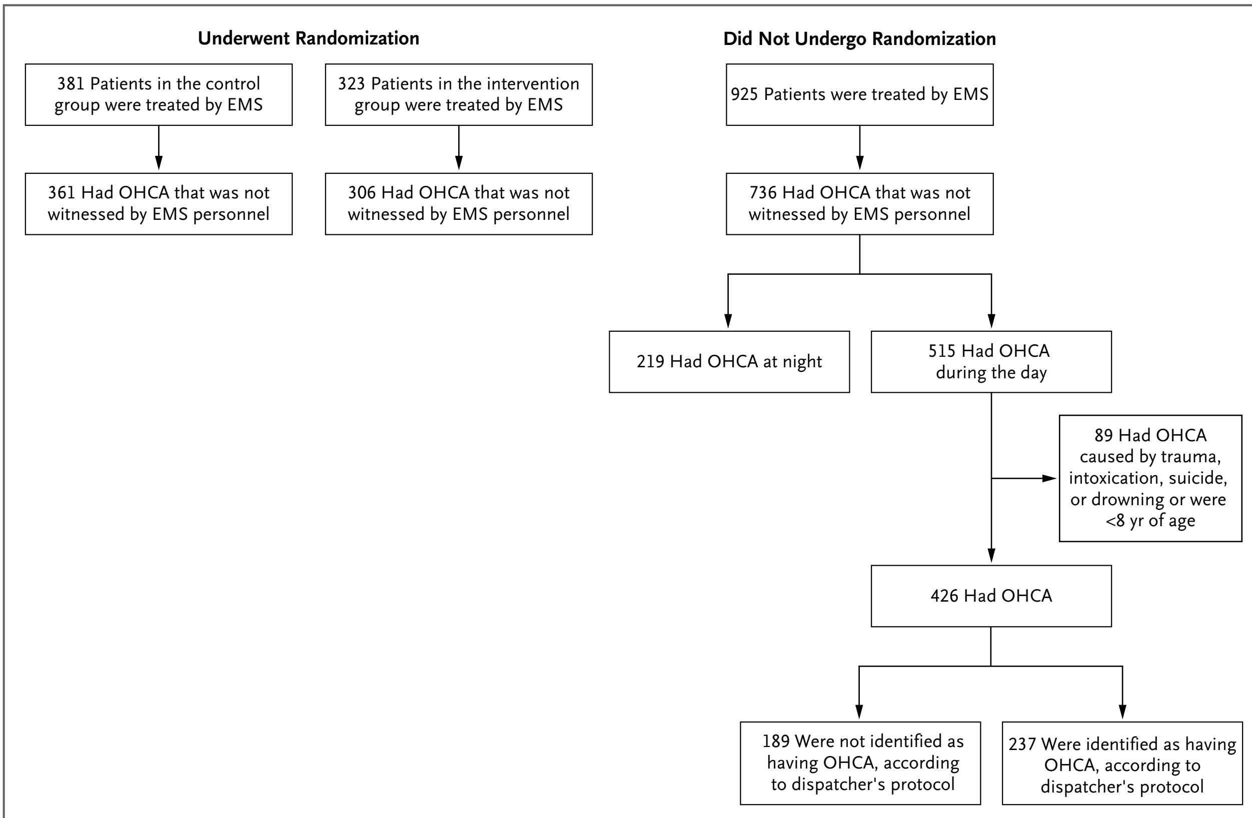

Figure 3. All Patients with Out-of-Hospital Cardiac Arrest in Stockholm County during the Study Period.
The mobile-phone positioning system was activated by dispatchers in 667 cases of OHCA, and these cases were randomly assigned to either the intervention group or the control group. All OHCAs in Stockholm during the study period were recorded in the Swedish Cardiac Arrest Registry. A review of this registry showed that in 925 cases, the mobile-phone positioning system was not activated by dispatchers for various reasons. Dispatchers were instructed to not activate the system in cases of trauma, suicide, drowning, or intoxication, or in the case of OHCA in children younger than 8 years of age. The system was active between 6 a.m. and 11 p.m. Data on the time of the cardiac arrest were missing for two patients.

to perform bystander-initiated CPR in patients nearby who had an out-of-hospital cardiac arrest. The rate of the primary outcome of bystander-initiated CPR was significantly higher in cases in which the mobile-phone positioning system was activated than in cases in which it was not activated (62% vs. 48%), and the logistic-regression analysis showed that bystander-initiated CPR before the arrival of first responders or EMS personnel was independently associated with the dispatch of lay volunteers after activation of the mobile-phone positioning system.

The increase in the rate of bystander-initiated CPR was not the result of comprehensive public education or information campaigns. However, a study from Denmark showed an increase from 21% to 45% in the rate of bystander-initiated CPR over 9 years as a result of a nationwide promotion of CPR.[14]

The absence of significant differences in the baseline characteristics of the patients and cardiac arrests suggests that there was no selection bias at randomization. In this study, the mobile-phone positioning system was functional when either first responders (either a police or fire vehicle) or an ambulance that was first to arrive on the scene had relatively short response times. First responders arrive at the scene before an ambulance in about 40% of all out-of-hospital cardiac arrests.[15] Thus, we speculate that the mobile phone–based alerting system might have a greater effect in areas that lack first responders and that have low baseline rates of bystander-initiated CPR (even that performed by persons without prior training).

Two thirds of all out-of-hospital cardiac arrests occur at home[16]; these events are associated with low rates of bystander-initiated CPR and worse outcomes.[17] In more than two thirds of all cases in our study, in which lay volunteers who were trained in CPR started CPR, the cardiac arrest occurred in the patient's home. Our results suggest that a mobile-phone positioning system is a useful strategy for sending lay responders to treat all cardiac arrests, including those that occur at a patient's home.

Automated external defibrillators (AEDs) are usually placed in public places. A study in the Netherlands showed that mobile-phone text messages were successfully used to send lay responders who had registered street addresses within 1000 m from patients with suspected out-of-hospital cardiac arrest to perform CPR and use AEDs. This system was also used to send volunteers to patients' homes.[18] Future integration of mobile-phone positioning systems with AED registries may facilitate lay responders in locating the nearest AED and thereby increase efficacy in public-access defibrillation programs.

Other mobile-phone technologies have been developed and used to send lay volunteers to patients with suspected out-of-hospital cardiac arrest.[19] In our study, almost 10,000 people voluntarily joined the program without any financial compensation, and no major adverse events were reported. Other examples of engagement of large numbers of lay volunteers are initiatives that encourage public reporting of the location of AEDs.[20]

The provision of instructions over the telephone for how to perform CPR is a vital part of the emergency response in most communities.[21] CPR with telephone instructions is most commonly performed by untrained or elderly bystanders, and the quality of CPR may be impaired.[22] The aim of the current study was to increase the rate of bystander-initiated CPR by trained rescuers. We speculate that there might be an additional value to recruiting trained bystanders, even when another person has initiated CPR with instructions provided over the telephone. To reflect the purpose of the present study, CPR performed only by a person who was receiving telephone instructions (i.e., only by a person not trained in CPR) was not considered to be bystander-initiated CPR in the primary outcome analysis but was included in our secondary analysis. In both situations, CPR rates were significantly increased. The intervention may be less effective in areas with a high rate of CPR performed with the help of telephone instructions and an even higher baseline rate of bystander-initiated CPR than the rate in this study.

No significant between-group differences were seen in the secondary outcomes of return of spontaneous circulation and survival at 1 month. In a meta-analysis by Sasson et al.,[2] the number needed to treat with bystander-initiated CPR to prevent one death was between 24 and 36. The treatment effect of bystander-initiated CPR with an increase of 14 percentage points in the rate of CPR administered by trained responders was not powerful enough to affect the survival rate in our limited study population. To assess whether the increase in rates of bystander-initiated CPR from 48% to 62% is enough to improve the survival rate would require a much larger patient population. However, bystander-initiated CPR has repeatedly been shown to be associated with increased survival rates in large patient cohorts.[23,24] In a recent study by Hasselqvist et al., reported elsewhere in this issue of the *Journal*, bystander-initiated CPR, as compared with CPR administered after EMS arrival, was independently associated with an increased rate of 30-day survival (odds ratio, 2.15; 95% CI, 1.88 to 2.45; P<0.001).[25]

Although in our study population, the intervention was associated with an increase of 14 percentage points in the rate of bystander-initiated CPR by a trained layperson, the mobile-phone positioning system was activated in only about half of all the out-of-hospital cardiac arrests in the community. If our results were applied to the entire out-of-hospital cardiac arrest population, including cases in which the mobile-phone positioning system was not activated, the overall increase in bystander-initiated CPR as an effect of the intervention might have been less than what was seen in our study population. However, a more comprehensive identification of cardiac arrests by dispatchers, extension of the use of the mobile-phone positioning system to assist patients with cardiac arrest that occurs at night, technical improvements in the system, and enrollment of additional lay rescuers may increase the effect of the intervention.

Differences among cities and countries in technical, legal, educational, social, and economic factors may influence the generalizability of our results. A sufficient number of lay volunteers who were trained in CPR is probably key to the current results and may not be transferred to other social and cultural contexts.

Our study has a few limitations. First, it was a single-center study that only involved one dispatch center, and it was not powered to analyze survival. Second, the time from cardiac arrest to the arrival of lay volunteers who were trained in CPR could not be measured objectively. Finally, the mobile-phone positioning system was not used at night or in cases of trauma, drowning, intoxication, or suicide or in persons younger than 8 years of age; thus, our results might not apply to out-of-hospital cardiac arrests that occur in such circumstances.

In conclusion, in the current study, the use of a mobile-phone positioning system for location and dispatch of lay volunteers who were trained in CPR to patients nearby who had out-of-hospital cardiac arrest significantly increased the rate of bystander-initiated CPR. The arrival of these volunteers had little effect on clinical outcomes.

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Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

REFERENCES

1. Waalewijn RA, Tijssen JG, Koster RW. Bystander initiated actions in out-of-hospital cardiopulmonary resuscitation: results from the Amsterdam Resuscitation Study (ARRESUST). Resuscitation 2001; 50:273-9.
2. Sasson C, Rogers MA, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. Circ Cardiovasc Qual Outcomes 2010;3:63-81.
3. Bradley SM, Rea TD. Improving bystander cardiopulmonary resuscitation. Curr Opin Crit Care 2011;17:219-24.
4. Isbye DL, Rasmussen LS, Ringsted C, Lippert FK. Disseminating cardiopulmonary resuscitation training by distributing 35,000 personal manikins among school children. Circulation 2007;116: 1380-5.
5. Groeneveld PW, Owens DK. Cost-effectiveness of training unselected laypersons in cardiopulmonary resuscitation and defibrillation. Am J Med 2005;118: 58-67.
6. Drane C, Macnaughtan M, Scott C. Positioning GSM telephones. IEEE Communications 1998;36:46-54, 59.
7. Ringh M, Fredman D, Nordberg P, Stark T, Hollenberg J. Mobile phone technology identifies and recruits trained citizens to perform CPR on out-of-hospital cardiac arrest victims prior to ambulance arrival. Resuscitation 2011;82:1514-8.
8. Yonekawa C, Suzukawa M, Yamashita K, et al. Development of a first-responder dispatch system using a smartphone. J Telemed Telecare 2014;20:75-81.
9. Befolkning och befolkningsforandringar (in Swedish). (http://www.tmr.sll.se/Global/Dokument/Statistik/arsstatistik/2012/Kapitel2_2012.pdf). (Stockholm: Growth and Regional Planning Administration).
10. Chen MY, Sohn T, Chmelev D, et al. Practical metropolitan-scale positioning for GSM phones. Lecture Notes in Computer Science 2006;4206:225-42.
11. Karolinska Institutet. SMS-lifesaver (http://www.smslivraddare.se).
12. Kuth DE. The art of computer programming, volume 2: seminumerical algorithms. 2nd ed. Reading, MA: Addison-Wesley, 1981.
13. Newcombe RG. Improved confidence intervals for the difference between binomial proportions based on paired data. Stat Med 1998;17:2635-50.
14. Wissenberg M, Lippert FK, Folke F, et al. Association of national initiatives to improve cardiac arrest management with rates of bystander intervention and patient survival after out-of-hospital cardiac arrest. JAMA 2013;310:1377-84.
15. Nordberg P, Hollenberg J, Rosenqvist M, et al. The implementation of a dual dispatch system in out-of-hospital cardiac arrest is associated with improved short and long term survival. Eur Heart J Acute Cardiovasc Care 2014;3:293-303.
16. Iwami T, Hiraide A, Nakanishi N, et al. Outcome and characteristics of out-of-hospital cardiac arrest according to location of arrest: a report from a large-scale, population-based study in Osaka, Japan. Resuscitation 2006;69:221-8.
17. Folke F, Gislason GH, Lippert FK, et al. Differences between out-of-hospital cardiac arrest in residential and public locations and implications for public-access defibrillation. Circulation 2010;122:623-30.
18. Zijlstra JA, Stieglis R, Riedijk F, Smeekes M, van der Worp WE, Koster RW. Local lay rescuers with AEDs, alerted by text messages, contribute to early defibrillation in a Dutch out-of-hospital cardiac arrest dispatch system. Resuscitation 2014;85:1444-9.
19. PulsePoint (http://pulsepoint.org/app).
20. Merchant RM, Asch DA, Hershey JC, et al. A crowdsourcing innovation challenge to locate and map automated external defibrillators. Circ Cardiovasc Qual Outcomes 2013;6:229-36.
21. Rea TD, Eisenberg MS, Becker LJ, Murray JA, Hearne T. Temporal trends in sudden cardiac arrest: a 25-year emergency medical services perspective. Circulation 2003;107:2780-5.
22. Dorph E, Wik L, Steen PA. Dispatcher-assisted cardiopulmonary resuscitation: an evaluation of efficacy amongst elderly. Resuscitation 2003;56:265-73.
23. Valenzuela TD, Roe DJ, Cretin S, Spaite DW, Larsen MP. Estimating effectiveness of cardiac arrest interventions: a logistic regression survival model. Circulation 1997;96:3308-13.
24. Holmberg M, Holmberg S, Herlitz J, Gårdelöv B. Survival after cardiac arrest outside hospital in Sweden. Swedish Cardiac Arrest Registry. Resuscitation 1998; 36:29-36.
25. Hasselqvist-Ax I, Riva G, Herlitz J, et al. Early cardiopulmonary resuscitation in out-of-hospital cardiac arrest. N Engl J Med 2015;372:2307-15.