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Clinical paper

Text message alert system and resuscitation outcomes after out-of-hospital cardiac arrest: A before-and-after population-based study



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Abstract

Introduction: This study aimed to investigate the association of a resuscitation bundle intervention including text message (TM) alert system and bystander cardiopulmonary resuscitation (CPR) and outcomes of out-of-hospital cardiac arrest (OHCA).

Methods: A population intervention study was conducted for resuscitation-attempted OHCA cases from 2013 to 2017 in selected districts in Seoul, Korea. A bundle intervention consisting of three components was implemented in May 2015: 1) community CPR training and organizing volunteer network, 2) installation of public access defibrillators (PAD) and 3) text message (TM) sent to registered volunteers to inform them about the OHCA event and nearest PAD. The study outcomes (bystander CPR, survival to discharge and good neurological outcome at hospital discharge) were compared between intervention period (after-intervention: May 2015 to December 2017) and control period (before-intervention: January 2013 to April 2015). A multivariable logistic regression analysis was performed to determine the effect of the intervention. Adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were calculated, adjusting for potential confounders. As a sensitivity analysis, propensity score matching (PSM) method was used for cases of the before period to the TM sent cases in the after period to balance covariate in the before and after groups. The same logistic regression model was evaluated with this PSM population.

Results: A total of 3194 eligible OHCA cases (1498 in before- and 1696 in after-intervention) were evaluated. The bystander CPR rate increased during the study periods (from 54.9% to 59.8%) ($p < 0.01$). OHCA outcomes improved from 9.0% to 12.7% for survival to discharge and from 4.5% to 8.3% for good neurological outcome (all $p < 0.01$). Compared with control periods, the AORs (95% CIs) for bystander CPR, survival to discharge and good neurological outcome of the intervention period were 1.25 (1.08–1.44), 1.84 (1.29–2.63) and 2.31 (1.44–3.70), respectively. Similar results were observed in the PSM population.

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Conclusion: The bundle intervention including TM alert service for OHCA was associated with better survival outcomes through an increase in bystander CPR.

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Keywords: Out-of-hospital cardiac arrest, Text messaging, Cardiopulmonary resuscitation, Outcomes

Introduction

Out-of-hospital cardiac arrest (OHCA) is an important public health burden in the world.^{1,2} Although it is known that early cardiopulmonary resuscitation (CPR) and defibrillation play a key role in the chain of survival of OHCA,^{3,4} it is difficult to reduce the time from collapse to the initiation of the resuscitation by emergency medical service (EMS) personnel. Thus, dispatcher-assisted CPR (DA-CPR) and public access defibrillator (PAD) programs have been implemented to gather bystander effort.^{5–9} In addition, since only a nearby layperson can provide a rapid resuscitation in a cardiac arrest situation, bystander alert systems have been added to them.^{10,11}

The layperson alert system is a mobile technology using program that alerts volunteers to go to OHCA patients and perform bystander CPR and early defibrillation with PADs. Since a nearby layperson has the advantage of arriving at the scene faster, this kind of system has spread to many countries.^{10,12–14} A randomized controlled trial was conducted in 2015 and demonstrated that an alert system allowed a layperson to provide more bystander CPR compared with controls.¹⁵ However, this trial did not show an improvement in survival outcome. The Dutch program is the only one that has shown an improvement in survival by increasing bystander CPR.¹⁶ However, since it was conducted in a rural area with long ambulance time, it is difficult to generalize the results to a metropolitan city.

In May 2015, the Seoul metropolitan city initiated the bundle intervention of three resuscitation programs: 1) community CPR training and organizing volunteer network, 2) the installation of PADs, 3) text message (TM) alert system that alerts a trained neighborhood volunteer to go to an OHCA victim and perform early CPR and defibrillation with PADs.

The aim of this study was to describe the results of the implementation of a community resuscitation bundle program and to evaluate whether these programs including the TM alert system would increase bystander CPR and improve OHCA outcomes.

Methods

Study setting

The national fire department exclusively operates the EMS system in Korea. Following the 2010 and 2015 American Heart Association (AHA) guidelines, ambulance crews provide CPR at the scene and during transport, but they cannot stop CPR unless the return of spontaneous circulation (ROSC) occurs.^{17,18} Since only a physician can declare death, they cannot declare death in the field. Seoul is a large metropolitan city, capital city of Korea. The population is approximately 10 million in an area of 605 km². One dispatch center is responsible for the entire city and adapted a DA-CPR protocol in late 2010. Seoul is composed of 25 administrative districts and 429 neighborhoods (neighborhoods were nested in district). One district consists of an average of 17 neighborhoods.

An average population of the neighborhoods is 20,000 in an average area of 1.5 km².

Intervention

In May 2015, Seoul launched the resuscitation bundle program, called the dispatch-activated neighborhood access defibrillation and cardiopulmonary resuscitation program (“NAD-CPR” program) in 5 districts serving a population of 2.2 million (Gangdong-gu, Gangbuk-gu, Nowon-gu, Seocho-gu, and Jungnang-gu). The intervention consisted of three programs below.

First, the CPR volunteer network was organized for those who agreed to register for the TM alert system. Participating districts’ health centers actively opened CPR training courses and explained the CPR volunteer network to the trainee. The trainees voluntarily registered themselves to the network after completing the course. The volunteers’ telephone number, workplace address, and home address were collected and transferred to the dispatch center to integrate with the EMS call system. For quality control of the CPR trainee, the volunteer registration remained valid for 2 years, and after that it was automatically removed. If someone want to remain in the network after two years, they were required to attend CPR renewal course and register again.

Second, the Seoul health authority expanded the installation of PADs. All PADs were registered in the National Emergency Medical Center and the PAD registry was developed and recorded for the cases.⁹ The active installation and registration of the PADs were guided by each district’s health authorities by the EMS Act.⁹

Third, a TM alert system was implemented. In Seoul, dispatcher asked two key questions regarding altered mental status and abnormal breathing for suspected arrest according to the DA-CPR protocol. When a cardiac arrest was suspected, the dispatchers pushed a button to send a short text message containing the location of the arrest and nearest PAD to registered volunteers within the same geographic neighborhood. In Korea, real-time location tracking is prohibited due to privacy act, so registered address information was used instead of fixed radius reflexing the address of the volunteers’ home or workplace.

The protocol for the TM alert service was only applied in daytime from 06:00 to 22:00, because the night was regarded as an ineffective time to alert volunteers.

The EMS crew and medical record reviewers who were employed to review the hospital outcomes by the Korea Centers for Disease Control and Prevention (CDC) were blinded to the study intervention.

Study design

This was a non-randomized, pre- and post-intervention trial. Since the intervention program started in May 2015, the period from January 2013 to April 2015 was defined as the pre-intervention period, and the period from May 2015 to December 2017 was defined as the post-intervention period.

Study population

We enrolled all OHCA patients with a presumed cardiac etiology who were more than 18 years old and who were treated by an EMS provider between January 2013 and December 2017 within the study area in Seoul. Those cases without an attempted resuscitation effort, cases that were witnessed by EMS providers or those that occurred at a nursing home or medical facility were excluded.

Data collection and variables

We collected data from the Korean OHCA Registry including the ambulance run sheet, dispatch record, cardiac arrest in-depth registry, and medical records for outcomes from the Korea CDC.¹⁹ We developed the TM alert system registry and linked it with OHCA registry. We reviewed linked OHCA registry and checked whether the TM sent case was a real cardiac arrest or not. Such cases were excluded if they were not a cardiac arrest or death was confirmed at the scene and not transferred to the emergency department (ED).

The main exposure was the study phase (before and after intervention period). The TM cases were defined as the cases for which an TM alert was sent. Other cases were defined as standard care (non-TM) cases.

We collected following factors: 1) demographics (age, gender, and comorbidities (diabetes, hypertension, heart disease, and stroke)), 2) community factors (date of arrest, call time (00:00–05:59, 06:00–11:59, 12:00–17:59, and 18:00–23:59), witness status, location of the arrest (public or private), primary electrocardiogram at the scene (shockable, PEA and asystole), bystander CPR, and bystander defibrillation), 3) EMS factors (EMS time intervals (response time interval, scene time interval, transport time interval), prehospital airway management (bag valve mask, endotracheal intubation, or supraglottic airway device), multi-tier response (MTR) (single-tier, ambulance MTR and fire engine MTR), 4) post-resuscitation care (percutaneous coronary intervention (PCI), targeted temperature management (TTM), and extracorporeal membrane oxygenation (ECMO)).

Main outcomes

The primary endpoint was provision of bystander CPR. The secondary endpoints were the survival to discharge and good neurological outcomes, which were classified as cerebral performance category I or II at discharge.

Statistical analysis

The basic information of the intervention program was compared by study regions: registered volunteers, registered PADs, and the number of TM alerts sent during the study period. A descriptive analysis was performed to demonstrate the distribution of the categorical variables (counts and proportions) and continuous variables (medians and inter-quartile ranges). The categorical variables were compared with chi-square test and the continuous variables were compared with Wilcoxon rank-sum test.

To evaluate the effect of the study phase on the outcome, multivariable logistic regression analysis was used. Adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were calculated with adjustment for potential confounders. Model 1 was adjusted for demographic factors (age, gender, and comorbidities); Model 2 was adjusted for the demographic factors from Model 1 as well as time factors (season, weekday, and call time) and arrest characteristics (witness status and location of arrest). Primary electrocardiogram was added for Model 2 on survival to discharge and good neurological outcome; Model 3 was adjusted for the factors from Model 2 as well as prehospital management (prehospital airway management and MTR) and post-resuscitation care factors (PCI, TTM and ECMO).

For the sensitivity analysis, we used a propensity score matching method population to evaluate the effects of TM sent on the study outcomes under an equivalent distribution of potential confounders. We matched the case of the before phase to the TM sent cases in the after phase to construct a 1:1 matched sample. Demographics (age, gender and comorbidities), time factors (season, weekend and call time) and arrest characteristics (witness status and location of arrest) were used to calculate the propensity score for the TM sent cases of after-phase. Each TM alert activated cases were matched to the

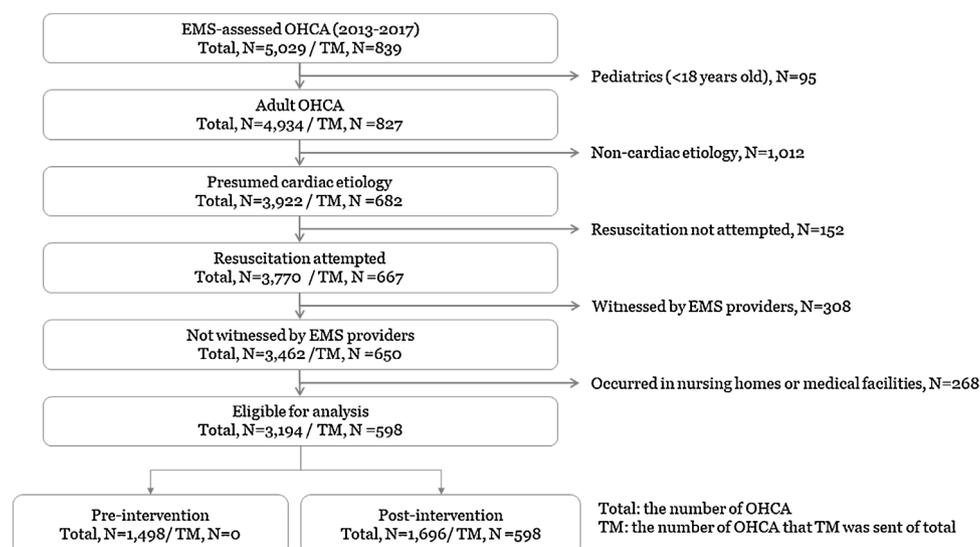


Fig. 1 – Patient and TM alert flow.

EMS, emergency medical service; OHCA, out-of-hospital cardiac arrest; TM, text message.

Table 1 – Demographics of all out-of-hospital cardiac arrests during the before- and after-intervention periods.

Variable	Before-intervention		After-intervention		All		P Value
	N	%	N	%	N	%	
Total	1498	100.0	1696	100.0	3194	100.0	
TM sent	0	0.0	598	35.3	598	18.7	
Gender							
Female	532	35.5	577	34.0	1109	34.7	0.38
Age group							0.26
15–40	67	4.5	81	4.8	148	4.6	
40–60	381	25.4	383	22.6	764	23.9	
60–80	681	45.5	782	46.1	1463	45.8	
80+	369	24.6	450	26.5	819	25.6	
median(q1–q3)	71 (58–80)		72 (59–80)		72 (58–80)		0.05
Bystander resuscitation							
CPR	823	54.9	1014	59.8	1837	57.5	<0.01
DEF	13	0.9	11	0.6	24	0.8	0.47
Event characteristics							
Witness	757	50.5	772	45.5	1529	47.9	<0.01
Public place	274	18.3	312	18.4	586	18.3	0.94
ECG							<0.01
VF/pulseless VT	271	18.1	335	19.8	606	19.0	
PEA	206	13.8	298	17.6	504	15.8	
Asystole	1021	68.2	1063	62.7	2084	65.2	
Response time interval, min							<0.01
0–3	220	14.7	132	7.8	352	11.0	
4–7	991	66.2	1174	69.2	2165	67.8	
7–11	225	15.0	317	18.7	542	17.0	
12+	62	4.1	73	4.3	135	4.2	
Median (q1–q3)	5 (4–7)		6 (5–7)		5.5 (4–7)		<0.01
Scene time interval, min							<0.01
0–3	91	6.1	12	0.7	103	3.2	
4–7	601	40.1	110	6.5	711	22.3	
7–11	534	35.6	624	36.8	1158	36.3	
12+	272	18.2	950	56.0	1222	38.3	
Median (q1–q3)	8 (6–10)		12 (10–15)		10 (7–13)		<0.01
Transport time interval, min							<0.01
0–3	247	16.5	354	20.9	601	18.8	
4–7	968	64.6	987	58.2	1955	61.2	
7–11	229	15.3	273	16.1	502	15.7	
12+	54	3.6	82	4.8	136	4.3	
Median (q1–q3)	5 (4–7)		5 (4–7)		5 (4–7)		0.39
Prehospital airway							<0.01
BVM	1186	79.2	521	30.7	1707	53.4	
ETI	46	3.1	277	16.3	323	10.1	
SGA	266	17.8	898	52.9	1164	36.4	
Multi-tier response							<0.01
Single-tier	1480	98.8	811	47.8	2291	71.7	
Ambulance MTR	18	1.2	773	45.6	791	24.8	
Fire engine MTR	0	0.0	112	6.6	112	3.5	
Post-resuscitation care							
PCI	46	3.1	67	4.0	113	3.5	0.18
TTM	76	5.1	89	5.2	165	5.2	0.82
ECMO	22	1.5	33	1.9	55	1.7	0.30

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Table 1 (continued)

Variable	Before-intervention		After-intervention		All		P Value
	N	%	N	%	N	%	
Outcomes							
PROSC	107	7.1	223	13.1	330	10.3	<0.01
Survival to discharge	135	9.0	216	12.7	351	11.0	<0.01
Good CPC	68	4.5	140	8.3	208	6.5	<0.01

TM, text message; Q, quartile; CPR, cardiopulmonary resuscitation; DEF, defibrillation; ECG, electrocardiogram; VF, ventricular fibrillation; VT, ventricular tachycardia; PEA, pulseless electrical activity; BVM, bag valve mask; ETI, endotracheal intubation; SGA, supraglottic airway; MTR, multi-tier response; PCI, percutaneous coronary intervention; TTM, targeted temperature management; ECMO, extracorporeal membrane oxygenation; PROSC, prehospital return of spontaneous circulation; Good CPC, good cerebral performance scale (1 or 2).

Table 2 – Multivariable logistic regression analysis of study outcomes by study phase (before- and after-intervention).

Outcomes	Period	Total	Outcome		Model 1 ^a			Model 2 ^b			Model 3 ^c		
			N	%	AOR	95% CI	AOR	95% CI	AOR	95% CI	AOR	95% CI	
Bystander CPR	Total	3194	1837	57.5									
	Before	1498	823	54.9	1.00			1.00					
	After	1696	1014	59.8	1.22	1.06	1.41	1.25	1.08	1.44			
Survival to discharge	Total	3194	351	11.0									
	Before	1498	135	9.0	1.00			1.00			1.00		
	After	1696	216	12.7	1.58	1.25	2.01	1.56	1.19	2.04	1.84	1.29	2.63
Good neurological outcome	Total	3194	208	6.5									
	Before	1498	68	4.5	1.00			1.00			1.00		
	After	1696	140	8.3	2.13	1.56	2.91	2.26	1.57	3.26	2.31	1.44	3.70

AOR, adjusted odds ratio; CI, confidence interval; CPR, cardiopulmonary resuscitation.

^a Model 1, adjusted for age, gender, and comorbidities (diabetes, hypertension, heart disease, and stroke).

^b Model 2 (bystander CPR), adjusted for age, gender, comorbidities (diabetes, hypertension, heart disease, and stroke), season, weekend, time of the arrest, witnessed, and location of arrest. Model 2 (survival to discharge and good neurological outcome), adjusted for age, gender, comorbidities (diabetes, hypertension, heart disease, and stroke), season, weekend, time of the arrest, witnessed, location of arrest, and initial ECG.

^c Model 3, adjusted for age, gender, comorbidities (diabetes, hypertension, heart disease, and stroke), season, weekend, time of the arrest, witnessed, location of arrest, initial ECG, prehospital management (prehospital advanced airway, multi-tier response), and post-resuscitation care (PCI, TTM, and ECMO).

control case of the before period with the closest propensity score. The same multivariable logistic regression model was used for this propensity score matched sample population.

As a secondary analysis for the cases in the intervention period, we compared the TM and standard care (non-TM) cases in the post-intervention period. The same multivariable logistic regression analysis was performed by setting TM as exposure.

All the statistical analyses were conducted using SAS software, version 9.4 (SAS Institute Inc., Cary, NC, USA). P values were based on a two-sided significance level of 0.05.

Ethics statements

The study was approved by the Institutional Review Boards of the Seoul National University Hospital (IRB No. H-1103-153-357).

Results

Basic information of the intervention program (“NAD-CPR” program)

As of December 2017, the number of registered volunteers was 63,924 and the number of PADs was 2045. TM alerts were sent for a total of 598 OHCA cases, and the median number of TM alerts sent per case was 133 (Supplement Tables 1 and 2).

Study population and TM alert flow

Of the 5029 EMS-assessed OHCAs during the study period, a total of 3194 patients were included in the study population. Of the 839 TM

Table 3 – Demographics of out-of-hospital cardiac arrests during the before- and after-intervention periods of propensity score matched sample population.

	Before-intervention		After-intervention		All		p Value
	N	%	N	%	N	%	
Total	598	100.0	598	100.0	1196	100.0	
TM sent	0	0.0	598	100.0	598	50.0	<0.01
Gender							
Female	215	36.0	212	35.5	427	35.7	0.86
Age group							0.93
15–40	31	5.2	28	4.7	59	4.9	
40–60	117	19.6	116	19.4	233	19.5	
60–80	279	46.7	274	45.8	553	46.2	
80+	171	28.6	180	30.1	351	29.3	
Median (q1–q3)	72 (60–81)		74 (61–82)		73 (60–82)		0.16
Bystander resuscitation							
CPR	326	54.5	409	68.4	735	61.5	<0.01
DEF	6	1.0	4	0.7	10	0.8	0.53
Event characteristics							
Witness	258	43.1	249	41.6	507	42.4	0.60
Public place	60	10.0	64	10.7	124	10.4	0.70
ECG							0.65
VF/pulseless VT	98	16.4	88	14.7	186	15.6	
PEA	73	12.2	80	13.4	153	12.8	
Asystole	427	71.4	430	71.9	857	71.7	
Response time interval, min							<0.01
0–3	87	14.5	53	8.9	140	11.7	
4–7	392	65.6	445	74.4	837	70.0	
7–11	96	16.1	88	14.7	184	15.4	
12+	23	3.8	12	2.0	35	2.9	
median(q1–q3)	5 (4–7)		5 (4–7)		5 (4–7)		0.12
Scene time interval, min							<0.01
0–3	36	6.0	2	0.3	38	3.2	
4–7	247	41.3	35	5.9	282	23.6	
7–11	207	34.6	253	42.3	460	38.5	
12+	108	18.1	308	51.5	416	34.8	
Median (q1–q3)	8 (6–10)		12 (10–14)		10 (7–13)		<0.01
Transport time interval, min							0.08
0–3	97	16.2	125	20.9	222	18.6	
4–7	389	65.1	351	58.7	740	61.9	
7–11	91	15.2	93	15.6	184	15.4	
12+	21	3.5	29	4.8	50	4.2	
Median (q1–q3)	5 (4–7)		5 (4–7)		5 (4–7)		0.29
Prehospital airway							<0.01
BVM	485	81.1	170	28.4	655	54.8	
ETI	12	2.0	119	19.9	131	11.0	
SGA	101	16.9	309	51.7	410	34.3	
Multi-tier response							<0.01
Single-tier	592	99.0	221	37.0	813	68.0	
Ambulance MTR	6	1.0	308	51.5	314	26.3	
Fire engine MTR	0	0.0	69	11.5	69	5.8	
Post-resuscitation care							
PCI	15	2.5	16	2.7	31	2.6	0.86
TTM	30	5.0	19	3.2	49	4.1	0.11
ECMO	7	1.2	6	1.0	13	1.1	0.78
Outcomes							

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Table 3 (continued)

	Before-intervention		After-intervention		All		p Value
	N	%	N	%	N	%	
PROSC	43	7.2	55	9.2	98	8.2	0.21
Survival to discharge	50	8.4	55	9.2	105	8.8	0.61
Good CPC	22	3.7	33	5.5	55	4.6	0.13

TM, text message; Q, quartile; CPR, cardiopulmonary resuscitation; DEF, defibrillation; ECG, electrocardiogram; VF, ventricular fibrillation; VT, ventricular tachycardia; PEA, pulseless electrical activity; ETI, endotracheal intubation; SGI, supraglottic airway; BVM, bag valve mask; PCI, percutaneous coronary intervention; TTM, targeted temperature management; ECMO, extracorporeal membrane oxygenation; ROSC, return of spontaneous circulation; Good CPC, good cerebral performance scale (1 or 2).

cases identified as OHCA that were treated and transported by EMS, a total of 598 TM cases were included in the analysis (Fig. 1).

Main analysis—comparison of before and after intervention period

1498 cases occurred in the before- and 1696 cases occurred in the after period. The bystander CPR rate increased from 54.9% to 59.8% ($p < 0.01$). The outcomes were improved from 9.0% to 12.7% for Survival to discharge and from 4.5% to 8.3% for good neurological outcome (all $p < 0.01$) (Table 1).

Compared with before period, the AOR (95% CIs) for bystander CPR was 1.25 (1.08–1.44) for the after periods. The AOR (95% CIs) was 1.84 (1.29–2.63) for survival to discharge and 2.31 (1.44–3.70) for good neurological outcome (Table 2).

Sensitivity analysis

A total of 1196 OHCA were included in the matched sample population (598 vs. 598). The bystander CPR rate increased significantly from 54.5% to 68.4% ($p < 0.01$). The outcomes were

improved from 8.4% to 9.2% for survival to discharge ($p = 0.61$) and from 3.7% to 5.5% for good neurological outcome ($p = 0.13$) (Table 3).

Compared with before period, the AOR (95% CIs) for bystander CPR was 1.83 (1.44–2.33) for the after periods. The AOR (95% CIs) was 2.13 (1.05–4.33) for survival to discharge and 2.62 (1.01–6.79) for good neurological outcome (Table 4).

Comparison between TM and standard care (non-TM) cases

Of the 1696 cases in the intervention period population, TM was sent for 598 cases and standard care was provided for 1098 cases (Supplement Table 3). Compared with standard care cases, the AOR (95% CIs) for bystander CPR was 2.00 (1.60–2.50) for the TM sent cases. The AOR (95% CIs) was 1.07 (0.69–1.66) for survival to discharge and 1.00 (0.58–1.73) for good neurological outcome (Table 5).

Discussion

We investigated the association between a resuscitation bundle intervention including TM alert system and bystander CPR and survival

Table 4 – Multivariable logistic regression analysis of study outcomes by study phase (before- and after-intervention) of propensity score matched sample population.

	Total	Outcome		Model 1 ^a			Model 2 ^b			Model 3 ^c		
		N	%	AOR	95% CI		AOR	95% CI		AOR	95% CI	
Bystander CPR	Total	1196	735	61.5								
	Before	598	326	54.5	1.00		1.00					
	After	598	409	68.4	1.81	1.43	2.29	1.83	1.44	2.33		
Survival to discharge	Total	1196	105	8.8								
	Before	598	50	8.4	1.00		1.00			1.00		
	After	598	55	9.2	1.13	0.74	1.71	1.20	0.74	1.96	2.13	1.05
Good neurological outcome	Total	1196	55	4.6								
	Before	598	22	3.7	1.00		1.00			1.00		
	After	598	33	5.5	1.68	0.94	2.99	2.32	1.14	4.71	2.62	1.01

AOR, adjusted odds ratio; CI, confidence interval; CPR, cardiopulmonary resuscitation.

^a Model 1, adjusted for age, gender, and comorbidities (diabetes, hypertension, heart disease, and stroke).

^b Model 2 (bystander CPR), adjusted for age, gender, comorbidities (diabetes, hypertension, heart disease, and stroke), season, weekend, time of the arrest, witnessed, and location of arrest. Model 2 (survival to discharge and good neurological outcome), adjusted for age, gender, comorbidities (diabetes, hypertension, heart disease, and stroke), season, weekend, time of the arrest, witnessed, location of arrest, and initial ECG.

^c Model 3, adjusted for age, gender, comorbidities (diabetes, hypertension, heart disease, and stroke), season, weekend, time of the arrest, witnessed, location of arrest, initial ECG, prehospital management (prehospital advanced airway, multi-tier response), and post-resuscitation care (PCI, TTM, and ECMO).

Table 5 – Multivariable logistic regression analysis of study outcomes by TM sent (TM versus standard care (non-TM)) in after-intervention phase cases.

	Total	Outcome		Model 1 ^a			Model 2 ^b			Model 3 ^c		
		N	%	AOR	95%CI		AOR	95%CI		AOR	95%CI	
Bystander CPR												
Total	1696	1014	59.8									
Standard	1098	605	55.1	1.00			1.00					
TM	598	409	68.4	1.76	1.43	2.17	2.00	1.60	2.50			
Survival to discharge												
Total	1696	216	12.7									
Standard	1098	161	14.7	1.00			1.00			1.00		
TM	598	55	9.2	0.64	0.45	0.89	0.93	0.62	1.38	1.07	0.69	1.66
Good neurological outcome												
Total	1696	140	8.3									
Standard	1098	107	9.7	1.00			1.00			1.00		
TM	598	33	5.5	0.63	0.41	0.96	0.99	0.59	1.65	1.00	0.58	1.73

AOR, adjusted odds ratio; CI, confidence interval; CPR, cardiopulmonary resuscitation.

^a Model 1, adjusted for age, gender, and comorbidities (diabetes, hypertension, heart disease, and stroke).

^b Model 2 (bystander CPR), adjusted for age, gender, comorbidities (diabetes, hypertension, heart disease, and stroke), season, weekend, time of the arrest, witnessed, and location of arrest. Model 2 (survival to discharge and good neurological outcome), adjusted for age, gender, comorbidities (diabetes, hypertension, heart disease, and stroke), season, weekend, time of the arrest, witnessed, location of arrest, and initial ECG.

^c Model 3, adjusted for age, gender, comorbidities (diabetes, hypertension, heart disease, and stroke), season, weekend, time of the arrest, witnessed, location of arrest, initial ECG, prehospital management (prehospital advanced airway, multi-tier response), and post-resuscitation care (PCI, TTM, and ECMO).

outcome of OHCA. Compared with the before-intervention period, bystander CPR increased (AOR, CI: 1.25, 1.08–1.44) and survival to discharge and good neurological outcomes also improved in the after-intervention period (AOR, CI: 1.84, 1.29–2.63 for survival and 2.31, 1.44–3.70 for good neurology). This result was more prominent in the sensitivity analysis for the population constructed by the propensity score matching method for the TM sent cases. The TM cases were more likely to receive bystander CPR than the standard care cases.

Layperson alert programs using mobile technology was expanded to support bystander resuscitation. A Dutch program applied TM alert system in the rural area and it showed that layperson could perform defibrillation faster and survival outcomes improved.^{13,16,20,21} A Swedish program had the advantage of checking the location of mobile phone users in real time with a mobile positioning system (MPS) and sending an TM alert to volunteers who were within 500 m of arrest. However, although a randomized controlled study showed that an intervention group provided more bystander CPR than controls, it was unclear whether the survival were improved.^{10,15} Studies from the US and Switzerland also showed that layperson could perform resuscitation earlier than the ambulance by app alert system.^{12,14} These studies investigated the potential of intervention using mobile technology under diverse conditions. However, large-scale community intervention studies have not been conducted to investigate whether mobile technology interventions can improve the survival outcomes of arrest patients in the metropolitan city.

We linked the TM alert system data with a nationwide OHCA database and compared before- and after-periods of study region. This method has the disadvantage of not being able to verify the volunteer response: received the TM or not, went to the scene or not, and performed resuscitation or not. However, from another point of view, it can be a strength of the study by demonstrating the overall effects of the intervention program including non-compliance of volunteer.

All the OHCA outcomes improved during the study period. This improvement was more prominent in the sensitivity analysis conducted on the propensity score matched sample population for the TM sent cases. In the final multivariable logistic model, improvement of survival outcomes was statistically significant event after adjusting for improved prehospital management and post-resuscitation care factors over time. Seoul is expanding mandatory CPR training and the DA-CPR program in accordance with the ten steps recommended by the Global Resuscitation alliance.¹⁹ According to this city-wide effort, bystander CPR rate increased over time.^{22,23} When the rate of increase in bystander CPR was in a plateau, new resuscitation bundle program was started according to the 2015 CPR guidelines, which made basic life support training easier, shorter, and more feasible. Due to the limitation of the study design of before and after comparison, it is hard to say that all improvement was the effects of the bundle intervention. However, there was no other newly implemented program during the study period and it is known that this kind of community intervention program have overall positive effects on the community as well as its own effect.²⁴ Thanks to this indirect community-wide benefit, the overall perception of bystander resuscitation may be increased in the community and people who did not registered as volunteers also became familiar with those. This is also part of the effect of intervention. Finally, as a result of the bundle intervention, increases in bystander CPR through the active community CPR training, subsequent volunteer network organization, and TM alert system were associated with improved OHCA outcomes.

Although PAD installation is an important part of the intervention program, provision of bystander defibrillation was low during the entire study period. There can be several reasons. Installation of PADs was not enough or laypeople were unfamiliar with PAD and could not find PADs.²⁵ By the end of 2017, there are 2045 PADs installed for

2,228,975 population in the study area, which is not enough for volunteers to use.⁹ To increase bystander defibrillation, the PAD related chain of survival should be strengthened to increase PAD installation and ensure that the installed PAD is used.^{25–27}

Attempts to recruit laypersons using mobile technology will be an important solution for the low provision of bystander CPR and delayed defibrillation. The TM alert system can increase the resuscitation of the layperson and speed up the chain of survival.^{15,20,28} In this study, bystander CPR was increased, but no improvement was observed in the bystander defibrillation. To further improve survival, it is necessary to carry out several interventions together, including installing more PADs in the community and creating a more tailored design of the TM alert system.

Limitations

First, this study was not a randomized controlled trial. As a before- and after-intervention trial, there might have been unmeasured confounders over time other than intervention. Although larger outcome improvement was observed in this study compared with usual one as time goes by,²³ a randomized trial is needed for more robust evidence. Second, we compared the TM and standard care in the after-intervention periods. There may be other confounding factor, selection bias, and systemic difference between TM and standard care group other than TM transmission. More attention should be paid to interpreting the results. Third, we could not confirm whether volunteers went to the scene and provided CPR or not. Our database did not have information of bystanders. Further study using individual tracking technology would be needed in future. The last limitation is related to the generalizability of the study results. This study was performed in a metropolitan city with a dense population and intermediate EMS provider level.

Conclusions

OHCA patients treated in the period after implementation of a resuscitation bundle program including TM alert system to alert CPR-trained volunteers were more likely to receive bystander CPR and showed better outcomes when compared with OHCA patients in the period before implementation.

Author contributions

Drs. Shin SD and Lee SY had full access to all of the data in the study and take responsibility for the integrity of the data, as well as for the accuracy of the data analysis.

Study concept and design: Dr. Shin SD.

Acquisition, analysis, and interpretation of the data: Drs. Lee SY and Shin SD.

Drafting of the manuscript: Dr. Lee SY.

Critical revision of the manuscript for important intellectual content:

Drs. Song KJ, Hong KJ, Ro YS, Kong SY, and Lee YJ.

Statistical analysis: Drs. LEE SY and Ro YS.

Obtained funding: Dr. Shin SD.

Administrative, technical, or material support: Drs. Song KJ, Hong KJ, and Lee YJ.

Study supervision: Drs. Shin SD and Song KJ.

Conflict of interest statement

There are no potential conflicts of interest for all the authors in this study.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.resuscitation.2019.01.045>.

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