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Effect of national implementation of utstein recommendation from the global resuscitation alliance on ten steps to improve outcomes from Out-of-Hospital cardiac arrest: a ten-year observational study in Korea

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ABSTRACT

Objectives The Utstein ten-step implementation strategy (UTIS) proposed by the Global Resuscitation Alliance, a bundle of community cardiopulmonary resuscitation (CPR) programs to improve outcomes after out-of-hospital cardiac arrests (OHCAs), has been developed. However, it is not documented whether UTIS programs are associated with better outcomes or not. The study aimed to test the association between the UTIS programme and better outcomes after OHCA.

Methods The study was a before- and after-intervention study. Adults OHCAs treated by emergency medical service (EMS) from 2006 to 2015 in Korea were collected, excluding patients witnessed by ambulance personnel and without outcomes. Phase 1 (2009–2011) after implementing three programs (national OHCA registry, obligatory CPR education, and public report of OHCA outcomes), and phase 2 (2012–2015) after implementing two programs (telephone-assisted CPR and EMS quality assurance programme) were compared with the control period (2006–2008) when no UTIS programme were implemented. The primary outcome was good neurological recovery (cerebral performance scale 1 or 2). We tested the association between the phases and outcomes, adjusting for confounders using a multivariate logistic regression model to calculate adjusted odds ratios (AORs) with 95% confidence intervals (CIs).

Results A total of 1 28 888 eligible patients were analysed. The control, phase 1, and phase two study groups were 19.4%, 30.5%, and 50.0% of the whole, respectively. There were significant changes in pre-hospital ROSC (0.8% in 2006 and 7.1% in 2015), survival to discharge (3.0% in 2006 and 6.1% in 2015), and good neurological recovery (1.2% in 2006 and 4.1% in 2015). The AORs (95% CIs) for good neurological recovery were 1.82 (1.53–2.15) or phase 1 and 2.21 (1.78–2.75) for phase two compared with control phase.

Conclusion The national implementation of the five UTIS programs was significantly associated with better OHCA outcomes in Korea.

Strengths and limitations of this study

- The study tested the association between implementation of five national CPR programs of ten UTIS programs proposed by the Global Resuscitation Alliance and better outcomes using nationwide OHCA data. All national OHCAs who were transported by fire-based ambulance services were collected with very high representativeness.
- The degree of implementation or real change by implementation were not fully measured. This might be related with measurement bias. This study relates outcome to the implementation of some of the ten steps. Some of these steps can be fully or partially implemented and until now there are defined no common tool for assessing the individual steps.
- A natural change by years could not be completely adjusted for, even though we adjusted for individual risk factors when calculating the effect size. The before- and after-intervention study has those limitations.
- Emergency medical services with intermediate service level in Korea were different North America or European countries where advanced life support are given to OHCA at the field. Therefore the generalisation should be cautious.

BACKGROUND

Out-of-hospital cardiac arrest (OHCA) is a serious public health problem due to high incidence and low survival rates worldwide.[1–3] To improve the survival rates, community, emergency medical services (EMSs), and hospital efforts should be closely linked on the basis of evidence and scientific guidelines.[4–8] However, the implementation of evidence-based cardiopulmonary resuscitation (CPR) programs has been difficult due to socioeconomic, cultural, administrative, and behavioural barriers.

The Utstein Implementation Meeting was held in 2015 in Stavanger, Norway to discuss ways to implement scientific recommendations at the community level. From this meeting, the ten programs and ten actions for improving outcomes after OHCA were agreed as core public health CPR programs, The Utstein Ten-step Implementation Strategy (UTIS). The UTIS recommended the followings steps derived from expert consensus: (1) Cardiac arrest registry, (2) Telephone-assisted CPR, (3) High-performance CPR, (4) Rapid dispatch, (5) Measurement of professional resuscitation, (6) Automatic external defibrillator (AED) programme for first responders, (7) Smart technologies for CPR and AED use, (8) Mandatory training for CPR and AED, (9) Accountability, and (10) Culture of excellence. The UTIS was agreed and accepted by the Global Resuscitation Alliance, a new international collaborating organisations for facilitating and implementing the UTIS to the communities, in the following meeting during the EMS 2016 in Copenhagen.

Although the UTIS was derived from scientific findings in many studies and experiences in different communities, the extent of the impact of implementing the UTIS CPR programs at the national level on outcomes is unclear. The goal of this study was to test the association between national implementation of the UTIS programs and outcomes of OHCA, as well as to test the interaction effect of the implementation of UTIS on outcomes across bystander CPR groups.

METHODS

This is a before- and after-intervention study to test the association between the national implementation of novel CPR programs and outcomes after OHCA. The Korea Centres for Disease Control and Prevention (CDC) approved the use of all data, and the study was approved by the Institutional Review Board of the study site.

Study setting

Approximately 50 million people live in a 99 000 km^2 area of land, where there were multiple regional and local government / hospital organisations: in 2015, there were 17 provinces and 253 local health departments (including 253 local health centres), 17 provincial fire departments, 200 local EMS agencies (966 ambulance stations and 1282 ambulances), and 546 emergency departments (EDs) (20 level one regional EDs, two specialty EDs, 124 level two local EDs, 274 level three emergency rooms, and 126 level four non-designated urgent facilities).

The Ministry of Health and Welfare EMS programme is responsible for emergency care services, acts and regulations, budgeting and policy planning. The Korea Centres for Disease Control and Prevention (CDC) is responsible for the community CPR programme by developing national standards and education programs. The National Medical Centre is responsible for hospital-based emergency care through the ED evaluation programme and reimbursement programs for hospital emergency care. The Central Fire Services (CFS) is responsible for pre-hospital ambulance services related to EMS.[9 10]

The 2005 and 2010 CPR guidelines recommended by the International Liaison Committee on Resuscitation (ILCOR) were accepted by the academic societies and implemented in the CPR training for lay persons, first responders, and EMS providers in 2006 and 2011, respectively.[11 12] The EMS CPR protocol was developed by EMS medical directors in 2011 on the basis of 2010 guidelines. The protocol allowed the EMS providers to perform chest compression and automatic defibrillation, and endotracheal intubation or supraglottic airway under direct medical control during prehospital CPR. The epinephrine or other resuscitation drugs were not permitted to infuse. The termination of resuscitation declared by emergency medical technicians was not allowed and all OHCAs should be transported to the emergency department with providing CPR on ambulance transport if the patients did not achieve the prehospital return of spontaneous circulation.

Data sources

The Korea OHCA Registry (KOHCAR) of cardiac arrest patients transported by ambulance services since 2006 has been constructed by the Korea CDC in collaboration with the central fire services (CFS). The EMS run sheet, EMS CPR registry, and dispatch CPR registry were merged into one EMS-assessed cardiac arrest database by the EMS quality committee of the CFS, which was sent to the Korea CDC. The Korea CDC cleaned the database of hospital information and reviewed the hospital records regarding inpatient care and outcomes.[9 10 13 14] The KOHCAR was developed on the basis of recommendations from the international OHCA database and has been modified several times to fit the needs of health policy and planning, cost-effective data collection, and academic requirements.

Data quality management (DQM) was performed in two steps. First, the CFS educated and trained EMTs (mostly level 1) to record EMS data through the data dictionary of EMS record variables and education programme. Medical oversight for each case was performed by EMS medical directors. Second, the Korea CDC educated and trained the hospital medical record reviewers (approximately 15 persons), who were employed by the Korea CDC and worked only for the medical record review programme. They were trained on data dictionary and case review protocols and dispatched to all hospitals to gather information on hospital care and outcomes. The first and second steps were supported by the same DQM committee members, consisting of EMS physicians, epidemiology and statistical experts, cardiologists, and medical record review experts. Every month, the DQM reviewed the collected data from the CFS and Korea CDC and sent feedback to both government partners.

Study population

All adult patients (older than 15 years) with OHCAs and with cardiac aetiology transported by ambulance services between 2006 and 2015 were selected. We excluded patients who did not receive resuscitation in the field or during ambulance transport, patients who suffered an arrest at a hospital ED, arrests that were witnessed by EMS providers, and patients for whom outcome information was not available.

National interventions and study groups

To decide whether the UTIS programme was or was not implemented in a community, each programme was defined using a standard operational definition agreed to by the consensus of the study authors and the attendees of the GRA meeting at the EMS ASIA 2016 Congress (See Appendix 1 for the UTIS implementation status checklist that was discussed in the meeting).

The national intervention was defined as programs introduced under a new Act Article related to community, EMS, and hospital CPR programs among the UTIS programs. We finally selected and defined five of ten programs to make up a national intervention as follows: (1) Korea OHCA Registry (2008) (2) Telephone-assisted CPR (2011) (3) High performance CPR programme (not implemented), (4) Rapid dispatch (2015), (5) Measurement of professional resuscitation (not implemented), (6) AED programme for first responders (not implemented), (7) Smart technology for CPR and AED (not implemented), (8) Mandatory training programme for CPR and AED (2008). (9) Accountability (2008), and (10) Cultural excellence (2011). We defined the intervention year as 1 year after the Act was enacted in the national assembly or the government regulation process began.

The KOHCAR started the CAVAS project in 2008 and applied and was approved for status as national statistics in 2009. The telephone-assisted CPR programme was implemented in Seoul in 2011 and implemented throughout the country in 2012, with mandatory inclusion in the dispatch CPR registry under the Rescue and EMS Act. Mandatory training programs for legally defined first responders, such as drivers, schoolteachers, police officers, rescuers and guards, were started by the EMS Act in 2008. Another obligatory training programme for students and teachers was implemented in 2012 by the School Health Act. All students in each primary, middle, and high school are required to attend at least one session of CPR training during each school year. Every schoolteacher is expected to learn CPR every 3 years, and health and sports teachers should retrain annually. Accountability for CPR was implemented in 2009. All statistics on CPR were reported to the public and the media via an annual symposium and press reports since 2009 and sent to all organisations. The cultural excellence in CPR programme was selected because under the Rescue and EMS Act, EMS medical directors have been working at local fire departments as employed medical directors since 2012. Every individual OHCA case was reviewed by the directors and scored for feedback to EMS providers.

We defined the five interventions and control according to the year of implementation as follows: 1) KOHCAR (2009), 2) Telephone-assisted CPR (2012), 3) Mandatory CPR program (2009), 4) Accountability (2009), and 5) Cultural excellence (2012). From those set time points, we defined the three phases of the observational period: 1) Control phase (2006–2008), 2) Primary intervention (phase 1) (2009–2011) after implementing KOHCAR, Mandatory CPR training, and Accountability, and 3) Secondary intervention (phase 2) (2012–2015) after implementing the T-CPR programme and Cultural excellence, including EMS quality assurance programs (figure 1).

Data variables

We selected several potential confounders for outcomes. These confounders included age, gender, urbanisation level (metropolitan city >1 million population, urban/ suburban city >50 000 population, and rural <50 000 per county), place of the event (public, private, unknown), event witness (witnessed, unwitnessed), bystander CPR (yes or no), bystander defibrillation (yes or no), dispatch assistance (yes or no), cause (cardiac, trauma, poisoning, drowning, asphyxia/hanging, and other), primary ECG rhythm (VF/ pulseless VT, PEA, asystole), date and time of onset (season, weekday, and day/ night), number of members of ambulance crew, top level of EMS providers (level 1, level 2, lower), airway management (endotracheal intubation, supraglottic airway, bag-valve mask ventilation, passive oxygen ventilation), EMS defibrillation (yes or no), elapsed time intervals (response time interval (RTI), scene time interval (STI), transport time interval (TTI), trauma level of ED (level 1 to 4), achievement of pre-hospital ROSC, survival to discharge, and a measure of neurological recovery, such as cerebral performance category 1 or 2.

Outcome measure

The primary outcome was survival with good neurological recovery (CPC 1 or 2) at discharge. The secondary outcome was survival to discharge. The tertiary outcome was pre-hospital ROSC. All outcomes were measured by the Korea CDC medical record reviewers, who had visited the hospital to evaluate the medical records. They extracted information from the hospital discharge summaries, which are usually used for the national health insurance reimbursement programme.

Statistical analysis

Demographic findings were described as percentages (%) for categorical variables or medians (q1 and q3) and were compared using the Chi-square test or Wilcoxon rank sum test with the significance level (p value<0.05). We estimated the crude incidence rates (IRs) for 1 00 000 population of each year. The IRs were calculated from the total number of OHCA with all causes in all gender/ age

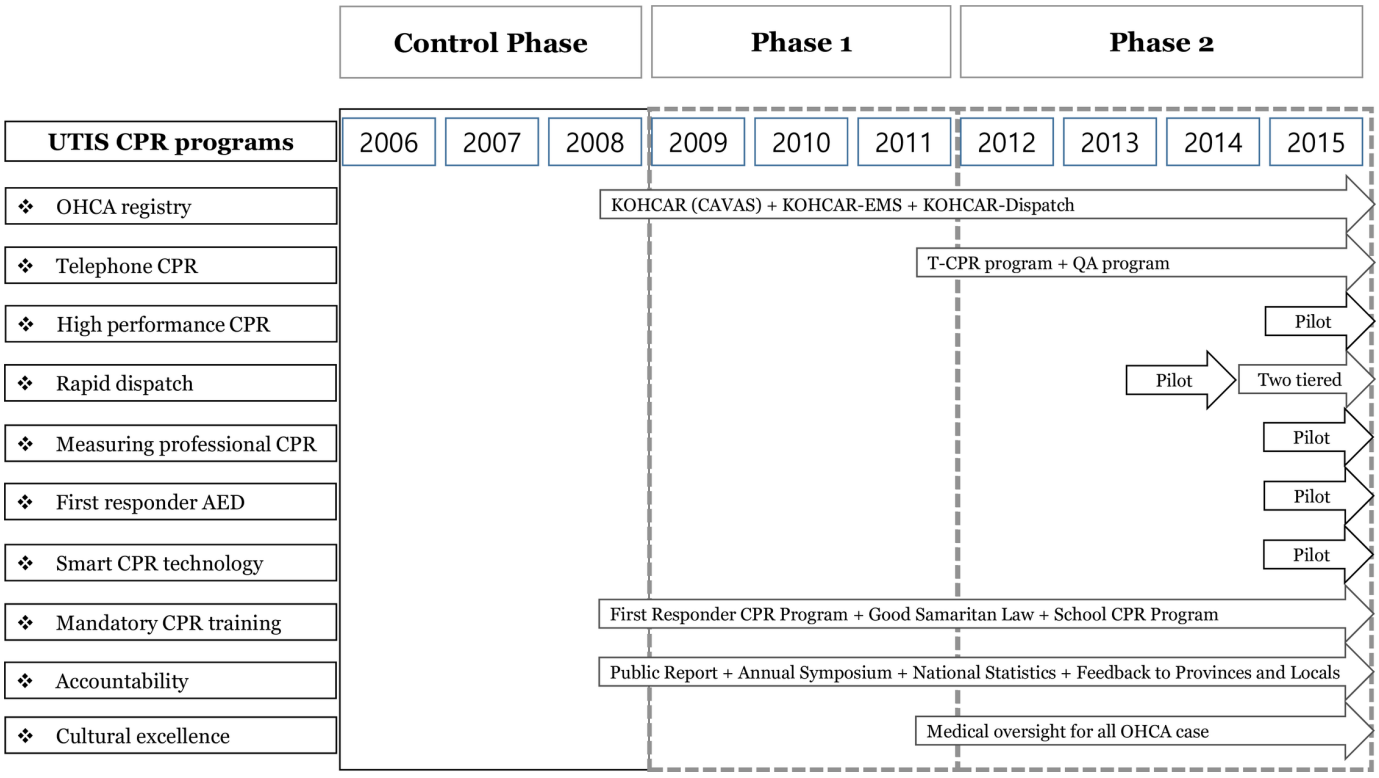

Figure 1 National Implementation of Utstein Ten-step Implementation Strategy by study period. CPR, cardiopulmonary resuscitation; AED, automatic external defibrillation; KOHCAR, Korea out-of-hospital cardiac arrest registry; EMS, emergency medical services; T-CPR, telephone-assisted CPR; OA, quality assurance; OHCA, out-of-hospital cardiac arrest.

group divided by the total number of population multiplying 1 00 000. Potential risk factors were tested for trends by year. We tested the trend for age- and gender-standardised outcomes using the whole study population as a standard population. All trends were tested by the Cochran-Armitage test.

Each UTIS intervention was tested for the association with outcome variables, and then we tested the UTIS intervention phases 1 and 2 (phase 1 in 2009–2011 and phase 2 in 2012–2015) compared with the control phase group (2006–2008), adjusting for the potential confounders identified above. Potential confounders were selected to avoid the mediator effect. We performed a multivariate logistic regression analysis for the UTIS on the outcomes, adjusted for potential confounders such as age, gender, urbanisation level of the event location, place (private, public, unknown), event witness (witnessed, unwitnessed, unknown), primary ECG rhythm (VF/pulseless VT, PEA, and asystole), response time intervals from call to ED arrival, scene time interval (STI) from arrival to the scene and departure to ED, advanced airway management (ETI, SGA, BVM, PV), level of ED (level 1 to 4), and implemented international CPR guidelines (2005 vs. 2010) for all patients. The 2005 and 2010 guideline were implemented during 2006–2010 and 2011–2015, respectively.

Additionally, interaction analysis was performed using an interaction model with the interaction term (study phase*bystander CPR), which was added to the final multivariate logistic regression model.

We performed the sensitivity analysis for appropriate comparison on the Utstein OHCA population who had cardiac aetiology, witnessed status, and initial shockable rhythm using the same multivariable logistic regression according to study period on outcomes.

All statistical analyses were performed using SAS software, version 9.4 (SAS institute Inc., Cary, NC, USA).

RESULTS

Demographics

Of 229,361 OHCAs during the study period, a total of 1 28 888 eligible patients were analysed, excluding patients who were less than age 15 (n=4478), had non-cardiac etiologies for arrest (n=68 152), for whom resuscitation was not attempted (n=23 807), whose arrest was witnessed in an ambulance (n=39 090), or who did not have available hospital outcome information (n=127). (figure 2)

The demographics among study groups are compared in table 1. Compared with the control group, the phase 1 and 2 groups had the following characteristics: older, predominantly female, occurred more often in private places, more shockable rhythms, less witnessed, more bystander CPR, staffing with more level 1 EMTs, more members in the ambulance crew, longer response times, increased scene time intervals, more advanced airway management, and higher trauma levels of ED (all p values<0.001). Patients included in Phases 1 and 2 had

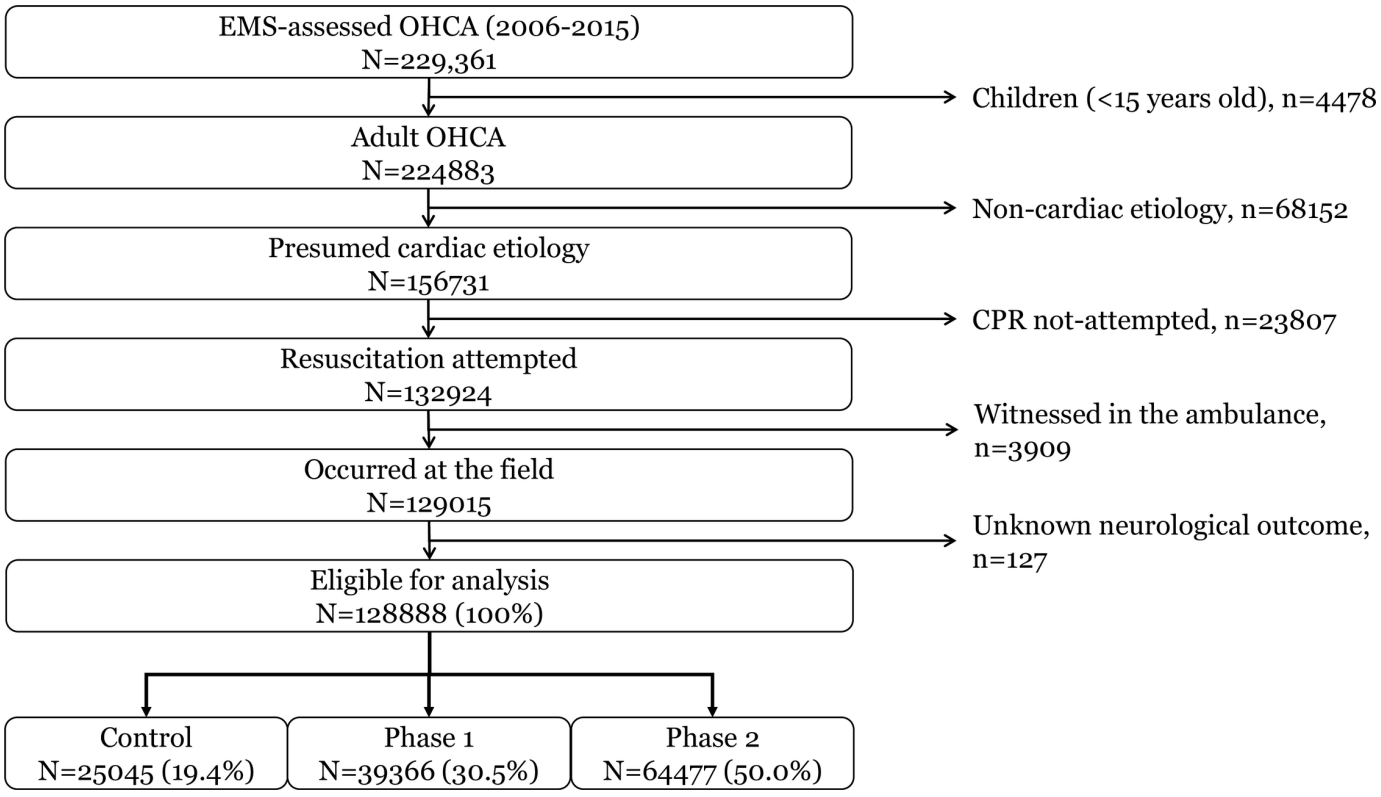

Figure 2 Study subjects. EMS, emergency medical service; OHCA, out-of-hospital cardiac arrest; CPR, cardiopulmonary resuscitation.

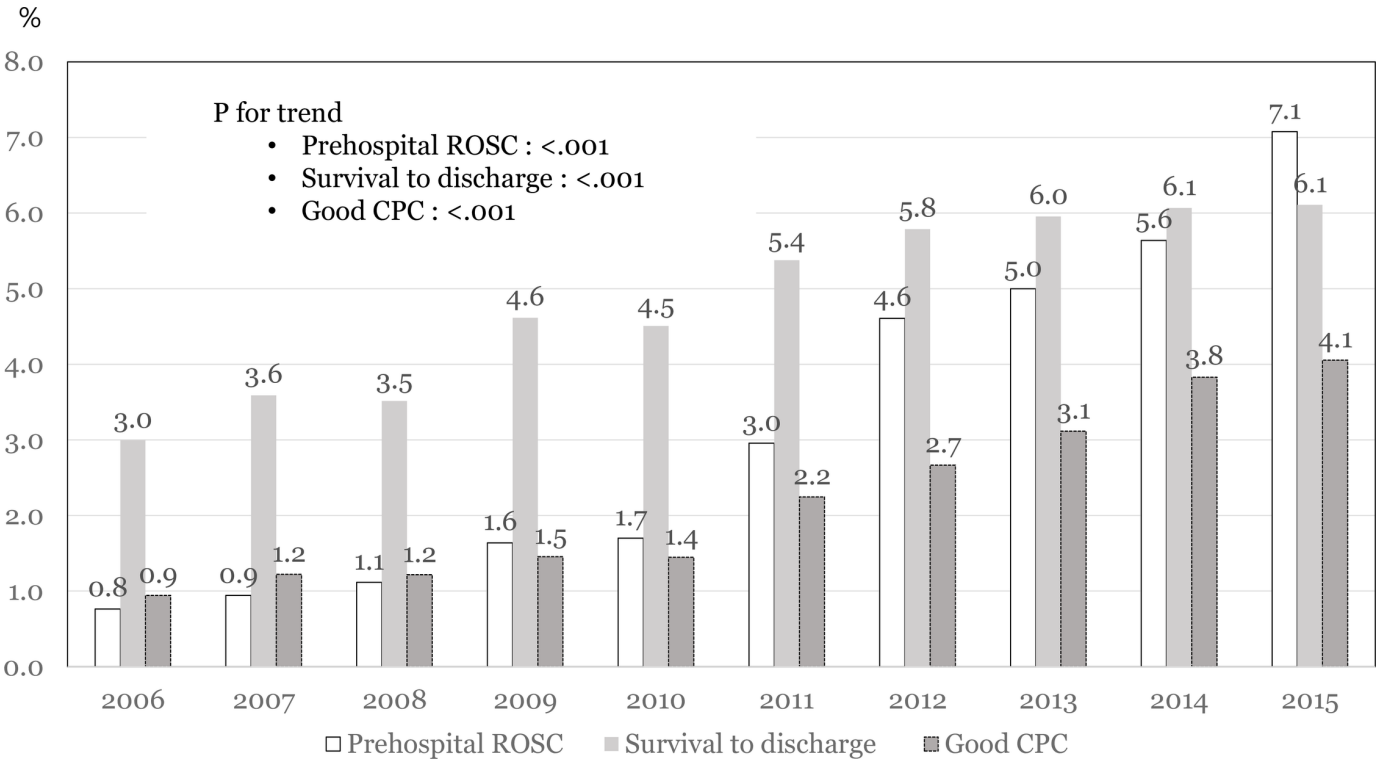

Figure 3 Longitudinal trend of outcomes in out-of-hospital cardiac arrest in Korea. ROSC, return of spontaneous circulation; CPC, cerebral performance scale.

Table 1 Demographic findings of study population among intervention phase groups and control

	All		Control		Phase 1		Phase 2		p-Value
Variables	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	
Total	128888	100.0	25045	100.0	39366	100.0	64477	100.0	
Age									<0.001
15–39, years	7004	5.4	1835	7.3	2262	5.7	2907	4.5	
40–59, years	33451	26.0	7431	29.7	10590	26.9	15430	23.9	
60–79, years	59360	46.1	11661	46.6	18389	46.7	29310	45.5	
80–years	29073	22.6	4118	16.4	8125	20.6	16830	26.1	
Median (q1-q3)	56 (70–79)		53 (66–76)		55 (69–78)		58 (72–80)		
Gender									<0.001
Female	45913	35.6	8637	34.5	13789	35.0	23487	36.4	
Male	82975	64.4	16408	65.5	25577	65.0	40990	63.6	
Metropolis									0.486
Non-metropolis	74188	57.6	14444	57.7	22736	57.8	37008	57.4	
Metropolis	54700	42.4	10601	42.3	16630	42.2	27469	42.6	
Place									<0.001
Public	26282	20.4	7421	29.6	7412	18.8	11449	17.8	
Private	101191	78.5	17265	68.9	31622	80.3	52304	81.1	
Unknown	1415	1.1	359	1.4	332	0.8	724	1.1	
Primary ECG									<0.001
VF/pulseless VT	8584	6.7	1327	5.3	1624	4.1	5633	8.7	
PEA	7241	5.6	907	3.6	1844	4.7	4490	7.0	
Asystole	113063	87.7	22811	91.1	35898	91.2	54354	84.3	
Witnessed									<0.001
No	71269	55.3	13190	52.7	21266	54.0	36813	57.1	
Yes	57619	44.7	11855	47.3	18100	46.0	27664	42.9	
Bystander CPR									<0.001
No	118110	91.6	24553	98.0	37499	95.3	56058	86.9	
Yes	10778	8.4	492	2.0	1867	4.7	8419	13.1	
Season									<0.001
MAR.-MAY	32731	25.4	6173	24.6	10152	25.8	16406	25.4	
JUN-AUG	28166	21.9	5692	22.7	8703	22.1	13771	21.4	
SEP-NOV	21998	17.1	4329	17.3	6664	16.9	11005	17.1	

Continued

Table 1 Continued

Variables	All		Control		Phase 1		Phase 2		p-Value
	N	%	N	%	N	%	N	%	
DEC-FEB	45993	35.7	8851	35.3	13847	35.2	23295	36.1	
Weekend									<0.001
Weekday	90739	70.4	17519	70.0	27696	70.4	45524	70.6	
Weekend	38149	29.6	7526	30.0	11670	29.6	18953	29.4	
Hour of the event									0.152
0–5 hour	19123	14.8	3743	14.9	5949	15.1	9431	14.6	
6–11 hour	41729	32.4	7779	31.1	12641	32.1	21309	33.0	
12–17 hour	36745	28.5	7088	28.3	11199	28.4	18458	28.6	
18–23 hour	31291	24.3	6435	25.7	9577	24.3	15279	23.7	
Level of EMT									<0.001
Level 1	89908	69.8	12888	51.5	24088	61.2	52932	82.1	
Level 2	32502	25.2	9336	37.3	13248	33.7	9918	15.4	
Level 3	6478	5.0	2821	11.3	2030	5.2	1627	2.5	
No of ambulance crew									
1	16187	12.6	6504	26.0	4418	11.2	5265	8.2	
2	88251	68.5	15403	61.5	28745	73.0	44103	68.4	
3	24450	19.0	3138	12.5	6203	15.8	15109	23.4	
Response time interval									<0.001
0–3 min	10289	8.0	2806	11.2	3491	8.9	3992	6.2	
4–7 min	66753	51.8	13845	55.3	21205	53.9	31703	49.2	
8–11 min	31796	24.7	5265	21.0	8992	22.8	17539	27.2	
12–15 min	11349	8.8	1696	6.8	3141	8.0	6512	10.1	
15 min	8701	6.8	1433	5.7	2537	6.4	4731	7.3	
Median (q1-q3)	7 (5–9)		6 (5–9)		6 (5–9)		7 (5–10)		
Scene time interval									<0.001
0–3 min	21491	16.7	7590	30.3	8490	21.6	5411	8.4	
4–7 min	47572	36.9	10195	40.7	16479	41.9	20898	32.4	
8–11 min	34675	26.9	4490	17.9	8935	22.7	21250	33.0	
12–15 min	15072	11.7	1663	6.6	3379	8.6	10030	15.6	
15 min	10078	7.8	1107	4.4	2083	5.3	6888	10.7	
Median (q1-q3)	7 (5–10)		5 (3–8)		6 (4–9)		8 (6–12)		

Continued

Table 1 Continued

Variables	All		Control		Phase 1		Phase 2		p-Value
	N	%	N	%	N	%	N	%	
Transport time interval									<0.001
0–3 min	19642	15.2	4617	18.4	5927	15.1	9098	14.1	
4–7 min	54292	42.1	10305	41.1	16460	41.8	27527	42.7	
8–11 min	25945	20.1	4631	18.5	7785	19.8	13529	21.0	
12–15 min	12641	9.8	2256	9.0	3878	9.9	6507	10.1	
15 min	16368	12.7	3236	12.9	5316	13.5	7816	12.1	
Median (q1-q3)	7 (4–11)		6 (4–11)		7 (4–11)		7 (4–11)		
Airway management									<0.001
ETI	3758	2.9	388	1.5	846	2.1	2524	3.9	
SGA	6483	5.0	596	2.4	908	2.3	4979	7.7	
BVM	80896	62.8	11146	44.5	23967	60.9	45783	71.0	
PV	37751	29.3	12915	51.6	13645	34.7	11191	17.4	
Level of ED									<0.001
Level 1	13972	10.8	2407	9.6	4252	10.8	7313	11.3	
Level 2	60469	46.9	10955	43.7	17515	44.5	31999	49.6	
Level 3	46452	36.0	9668	38.6	14931	37.9	21853	33.9	
Level 4	7995	6.2	2015	8.0	2668	6.8	3312	5.1	
Outcomes									
Prehospital ROSC	4722	3.7	243	1.0	837	2.1	3642	5.6	<0.001
Survival to discharge	6621	5.1	851	3.4	1908	4.8	3862	6.0	<0.001
Good CPC	3200	2.5	287	1.1	682	1.7	2231	3.5	<0.001

VF/V, ventricular fibrillation/ ventricular tachycardia; PEA, pulseless electrical activity; CPR,cardiopulmonary resuscitation; ETI, endotracheal intubation; SGA, supraglottic airway; BVM, bag-valve mask ventilation; PV, passive oxygen ventilation; ED, emergency department; ROSC: return of spontaneous circulation; CPC:,cerebral performance category.

Table 2 Age- and gender-standardised rates by year

	Total	Survival to discharge				Good CPC				
Year	N	Yes	CSR	SSR	95% CI	Yes	CSR	SSR	95% CI	
2006	6677	200	3.0	2.6	2.3 3.0	63	0.9	0.8	0.6	1.0
2007	7525	270	3.6	3.2	2.8 3.6	92	1.2	1.1	0.9	1.3
2008	10843	381	3.5	3.3	2.9 3.6	132	1.2	1.1	0.9	1.3
2009	11963	552	4.6	4.3	3.9 4.7	174	1.5	1.3	1.1	1.5
2010	13472	607	4.5	4.4	4.0 4.7	195	1.4	1.4	1.2	1.6
2011	13931	749	5.4	5.4	5.1 5.8	313	2.2	2.3	2.0	2.5
2012	14326	829	5.8	5.9	5.5 6.3	382	2.7	2.7	2.5	3.0
2013	15567	927	6.0	6.2	5.8 6.6	485	3.1	3.3	3.0	3.6
2014	16923	1027	6.1	6.7	6.3 7.1	648	3.8	4.3	4.0	4.6
2015	17661	1079	6.1	6.9	6.5 7.4	716	4.1	4.7	4.4	5.1

CSR, crude survival rate; SSR, age- and gender-standardised survival rate.

much better outcomes than those in the control phase (all p values<0.001).

Trend analysis

shows trends in crude incidence rate, bystander CPR, pre-hospital ROSC, survival to discharge, and good neurological recovery by year. There were significant changes from 2006 to 2015 in bystander CPR (1.2% in 2006 vs 16.4% in 2016), pre-hospital ROSC (0.8% in 2006 vs 7.1% in 2015), survival to discharge (3.0% in 2006 vs 6.1% in 2015), and good neurological recovery (1.2% in 2006 vs 4.1% in 2015). (p for trend <0.001) The prehospital ROSC was higher than survival to discharge rate in 2015.

The age-and gender-standardised survival rates (SSRs) were calculated using a direct standardisation that used the whole OHCA population during study period as a reference population (table 2). SSRs were 2.6 in 2006 vs 6.9 in 2015 per 100 OHCA person-years. SSRs with good neurological recovery were 0.8 in 2006 vs 4.7 in 2015 per 100 OHCA person-years.

Table 3 shows the trend of crude incidence rates and risk factors stratified by year. The crude incidence rates per 100 000 were 18.2 in 2006 and 41.1 in 2015, respectively. Metropolitan locations, season and weekend were not significantly changed by year (p for trend <0.001). The proportions of women and elderly patients older than 80 years, private places, and unwitnessed OHCAs, as well as shorter response time intervals (<4 min.), were increased (p for trend <0.001) and were correlated with poor outcomes. By contrast, proportions of bystander CPR and shockable rhythm, longer scene time intervals (>8 min.), increase in the number and level of EMT crew members, advanced airway management, and higher trauma level of ED of the destination hospital were increased (p for trend <0.001).

Main analysis

Table 4 shows the association between implementation phase and outcome from multivariate logistic regression analysis. AORs (95% CIs) on good neurological recovery in model 2 were 1.82 (1.53–2.15) for phase 1 and 2.21 (1.78–2.75) for phase 2. AORs (95% CI) in model 2 were 1.79 (1.62–1.98) (phase 1) and 1.78 (1.56–2.04) (phase 2) on survival to discharge and 2.20 (1.86–2.59) (phase 1) and 3.47 (2.84–4.24) (phase 2) on pre-hospital ROSC, respectively.

Interaction analysis

Interaction analysis for comparison of the effect size by study phase according to bystander cardiopulmonary resuscitation was performed (table 5). The implementation of phases 1 and 2 had different magnitudes of effects on good neurological recovery based on patient groups that received or did not receive bystander CPR. In terms of good neurological recovery, there was a significant interaction between phases 1 and 2 and bystander CPR (both p values<0.05). There was no significant interaction between pre-hospital ROSC in phases 1 or two with bystander CPR (both p values>0.05).

Sensitivity analysis

Sensitivity analysis was performed for the Utstein OHCA population. The AORs (95% CIs) on good neurological recovery in the model with adjusted for the full confounders (Model 2) were 1.32 (1.00–1.75) for phase 1 and 5.76 (4.56–7.28) for phase 2. AORs (95% CI) in model 2 were 1.22 (0.98–1.51) (phase 1) and 3.79 (3.14–4.58) (phase 2) on survival to discharge and 1.09 (0.74–1.60) (phase 1) and 14.36 (10.66–19.36) (phase 2) on pre-hospital ROSC, respectively (table 6).

DISCUSSION

The implementation of the Utstein ten-steps programs was associated with increase in prehospital ROSC, survival to discharge and good neurological recovery during 10 years observational period in Korea. During the study period, five programs were implemented, including CPR registry, obligatory CPR training, and public reports in

Table 3 Trend analysis on distribution of risk factors on outcomes according to year

Variables	All	Year										P for trend*
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
Total	128 888	6677	7525	10 843	11 963	13 472	13 931	14 326	15 567	16 923	17 661	
Crude incidence rate per 100,000†		18.2†	19.4†	28.1†	30.5†	33.4†	33.3†	35.8†	37.9†	39.7†	41.1†	
Age group												<0.001
15–39, years	5.4	7.7	7.4	7.1	6.7	6.0	4.7	4.9	4.7	4.4	4.0	
40–59, years	26.0	29.7	29.7	29.7	28.6	26.8	25.5	25.9	25.1	23.1	22.1	
60–79, years	46.1	46.8	46.8	46.2	46.3	46.8	47.0	46.2	45.7	45.2	44.9	
80–years	22.6	15.8	16.1	17.1	18.3	20.5	22.8	23.0	24.4	27.3	29.0	
Gender												<0.001
Female	35.6	34.5	33.6	35.1	34.0	35.4	35.5	36.2	35.7	37.0	36.7	
Male	64.4	65.5	66.4	64.9	66.0	64.6	64.5	63.8	64.3	63.0	63.3	
Metropolis												0.497
Non-metropolis	57.6	59.3	57.3	57.0	56.9	57.6	58.7	57.7	56.8	57.4	57.7	
Metropolis	42.4	40.7	42.7	43.0	43.1	42.4	41.3	42.3	43.2	42.6	42.3	
Place												<0.001
Public	20.4	38.5	34.7	20.6	19.4	18.2	19.0	18.8	18.0	17.5	17.0	
Private	78.5	60.6	62.8	78.3	79.7	81.1	80.2	80.1	80.9	81.3	81.9	
Unknown	1.1	0.9	2.5	1.1	0.9	0.8	0.9	1.1	1.1	1.2	1.1	
Primary ECG												<0.001
VF/pulseless VT	6.7	4.5	5.8	5.5	4.1	3.8	4.4	8.8	8.8	8.6	8.7	
PEA	5.6	2.4	3.1	4.7	4.1	4.6	5.3	6.4	6.8	6.6	7.8	
Asystole	87.7	93.1	91.1	89.8	91.8	91.5	90.3	84.8	84.3	84.7	83.5	
Witnessed												<0.001
No	55.3	53.9	53.7	51.2	53.1	54.9	53.9	55.5	59.1	57.5	56.2	
Yes	44.7	46.1	46.3	48.8	46.9	45.1	46.1	44.5	40.9	42.5	43.8	
Bystander CPR												<0.001
No	91.6	98.8	97.7	97.8	96.4	95.7	93.8	91.3	89.1	84.7	83.6	
Yes	8.4	1.2	2.3	2.2	3.6	4.3	6.2	8.7	10.9	15.3	16.4	
Season												0.338
MAR-MAY	25.4	24.8	24.9	24.3	25.6	26.1	25.7	24.6	25.4	25.3	26.4	
JUN-AUG	21.9	23.9	22.3	22.3	23.0	21.4	22.0	21.2	21.3	21.5	21.5	

Continued

Table 3 Continued

Variables	All	Year									P for trend*
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
SEP-NOV	17.1	16.9	17.1	17.7	17.2	17.1	16.5	17.2	17.5	17.1	16.5	
DEC-FEB	35.7	34.4	35.7	35.7	34.2	35.4	35.8	37.0	35.9	36.2	35.6	
Weekend												0.083
Weekday	70.4	69.3	70.1	70.2	70.2	70.7	70.1	71.0	70.2	70.8	70.5	
Weekend	29.6	30.7	29.9	29.8	29.8	29.3	29.9	29.0	29.8	29.2	29.5	
Hour of the event												0.000
0–5 hour	14.8	15.5	14.7	14.8	15.2	15.3	14.9	15.2	14.5	14.5	14.4	
6–11 hour	32.4	30.7	31.0	31.3	31.6	32.1	32.6	32.4	33.1	33.0	33.5	
12–17 hour	28.5	27.6	28.4	28.7	28.9	27.9	28.6	28.9	28.5	28.7	28.4	
18–23 hour	24.3	26.2	25.9	25.3	24.3	24.7	24.0	23.4	23.9	23.8	23.7	
Level of EMT												<0.001
Level 1	69.8	50.2	53.7	50.6	53.2	55.9	73.2	73.0	80.1	84.6	88.8	
Level 2	25.2	33.8	34.8	41.1	40.3	38.0	23.7	23.0	16.2	13.4	10.4	
Level 3	5.0	16.0	11.4	8.3	6.6	6.1	3.0	4.0	3.7	2.0	0.8	
No of ambulance crew												<0.001
1	12.6	36.7	29.2	17.1	10.9	16.3	6.6	10.1	13.6	7.0	2.9	
2	68.5	50.7	54.6	72.9	77.1	71.9	70.6	68.5	65.9	70.4	68.6	
3	19.0	12.6	16.3	9.9	11.9	11.8	22.8	21.3	20.6	22.6	28.5	
Response time interval												<0.001
0–3 min	8.0	13.1	11.4	9.9	8.7	8.9	9.0	7.5	7.2	6.5	4.0	
4–7 min	51.8	55.1	56.3	54.7	53.6	54.2	53.8	53.7	50.3	49.1	44.5	
8–11 min	24.7	19.9	20.3	22.2	23.6	22.4	22.6	23.5	24.9	27.3	32.1	
12–15 min	8.8	6.6	6.4	7.1	7.7	8.0	8.3	8.4	9.8	10.0	11.8	
15 min	6.8	5.3	5.6	6.1	6.5	6.5	6.3	6.8	7.7	7.1	7.7	
Scene time interval												<0.001
0–3 mi	16.7	32.0	30.4	29.2	24.8	22.0	18.3	14.9	9.5	8.2	2.4	
4–7 min	36.9	40.0	40.4	41.4	41.7	42.7	41.2	38.5	36.2	35.4	21.2	
8–11 min	26.9	17.2	17.7	18.5	21.1	22.0	24.8	27.3	32.2	32.1	39.1	
12–15 min	11.7	6.1	7.1	6.7	7.5	8.4	9.7	12.3	13.9	15.0	20.2	
15 min	7.8	4.7	4.5	4.2	4.9	4.9	6.1	7.0	8.2	9.3	17.1	

Continued

Table 3 Continued

Variables	All	Year									P for trend*
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
Transport time interval												<0.001
0–3 min	15.2	17.1	17.9	19.6	16.1	14.7	14.5	13.0	12.7	13.8	16.6	
4–7 min	42.1	42.4	41.9	39.9	42.0	41.9	41.5	42.3	42.9	42.8	42.7	
8–11 min	20.1	18.4	18.5	18.6	19.3	19.9	20.1	21.3	21.4	21.2	20.2	
12–15 min	9.8	9.3	8.5	9.2	9.5	9.7	10.3	10.2	10.2	10.3	9.8	
15 min	12.7	12.9	13.2	12.7	13.0	13.9	13.6	13.2	12.9	12.0	10.7	
Airway management												<0.001
ETI	2.9	1.3	1.8	1.6	1.9	1.8	2.7	2.5	2.6	3.7	6.5	
SGA	5.0	2.3	2.4	2.4	2.3	1.8	2.8	3.2	4.8	8.9	12.9	
BVM	62.8	38.0	44.7	48.4	52.4	56.8	72.2	73.6	70.9	70.9	69.2	
PV	29.3	58.4	51.1	47.7	43.5	39.6	22.3	20.8	21.8	16.6	11.4	
Level of ED												<0.001
Level 1	10.8	10.1	9.6	9.4	10.1	10.0	12.1	11.8	11.5	10.8	11.3	
Level 2	46.9	41.8	44.2	44.6	45.9	43.7	44.1	46.6	48.7	50.6	51.9	
Level 3	36.0	39.6	38.3	38.2	36.8	37.9	39.0	36.8	35.4	33.0	31.1	
Level 4	6.2	8.5	8.0	7.8	7.2	8.4	4.8	4.8	4.3	5.6	5.7	

VF/VT, ventricular fibrillation/ ventricular tachycardia; PEA, pulseless electrical activity; CPR, cardiopulmonary resuscitation; ETI, endotracheal intubation; SGA, supraglottic airway; BVM, bag-valve mask ventilation; PV, passive oxygen ventilation; ED, emergency department; ROSC, return of spontaneous circulation; CPC, cerebral performance category.
*P for trends were tested using the Cochran-Armitage test.
†Crude incidence rate=(total number of OHCA of each year/total number population of each year)*100 000. The OHCA includes the all causes of OHCA and all gender and age groups.

Table 4 Multivariable logistic regression analysis for outcomes of study phase comparing with control phase

Outcomes	Group	Total N	Outcome n	%	Model 1 AOR	95% CI		Model 2 AOR	95% CI	
Good CPC										
	Control	25 045	287	1.1	1.00			1.00		
	Phase 1	39 366	682	1.7	1.75	1.48	2.07	1.82	1.53	2.15
	Phase 2	64 477	2231	3.5	1.97	1.59	2.43	2.21	1.78	2.75
Survival to discharge										
	Control	25 045	851	3.4	1.00			1.00		
	Phase 1	39 366	1908	4.8	1.73	1.57	1.90	1.79	1.62	1.98
	Phase 2	64 477	3862	6.0	1.54	1.36	1.76	1.78	1.56	2.04
Prehospital ROSC										
	Control	25 045	243	1.0	1.00			1.00		
	Phase 1	39 366	837	2.1	2.21	1.87	2.60	2.20	1.86	2.59
	Phase 2	64 477	3642	5.6	3.58	2.94	4.36	3.47	2.84	4.24

Good CPC: cerebral performance scale 1 or 2.
Model 1: adjusted for implemented guideline, gender, age group, metropolis, place of the event, witness, primary ECG, date and time of event (season, weekend, hour).
Model 2: adjusted for implemented guideline, gender, age group, metropolis, place of the event, witness, primary ECG, date and time of event (season, weekend, hour), level of emergency medical technician, number of ambulance crew, response time interval, scene time interval, transport time interval, airway management method, level of emergency department transported to.
AOR, adjusted odd ratio; 95% CI, 95% confidence interval; ROSC, return of spontaneous circulation.

2008 and telephone-assisted CPR, and in-depth medical oversight for EMS CPR in 2011. The interventions were found to have significant effects on outcomes in both phases. The AORs for good CPC were 2.22 in phase 2 and 3.22 in phase 3.

There were several reports on the association between community implementation of CPR programs and improved outcomes. One report from Denmark showed the significant improvement in outcomes by implementation of community programs.[15] Analysis using

Table 5 Interaction analysis for comparison of the effect size by study phase according to bystander cardiopulmonary resuscitation

Outcome	Group	Bystander CPR (-) AOR	95% CI		Bystander CPR (+) AOR	95% CI		p Value for interaction
Good CPC								
	Control	1.00			1.00			
	Phase 1	1.62	1.36	1.93	3.33	1.87	5.92	0.017
	Phase 2	1.87	1.49	2.33	3.47	1.97	6.10	0.029
Survival to discharge								
	Control	1.00			1.00			
	Phase 1	1.70	1.54	1.88	2.49	1.69	3.68	0.058
	Phase 2	1.62	1.41	1.85	2.25	1.54	3.28	0.082
Prehospital ROSC								
	Control	1.00			1.00			
	Phase 1	2.03	1.72	2.41	2.99	1.70	5.26	0.194
	Phase 2	3.25	2.65	3.99	3.41	1.96	5.93	0.868

Good CPC: cerebral performance scale 1 or 2.
Adjusted for implemented guideline, gender, age group, metropolis, place of the event, witness, primary ECG, date and time of event (season, weekend, hour), level of emergency medical technician, number of ambulance crew, response time interval, scene time interval, transport time interval, airway management method, level of emergency department transported, bystander cardiopulmonary resuscitation (CPR), and interaction term (phase*bystander CPR).
AOR, adjusted odd ratio; 95% CI, 95% confidence interval; ROSC, return of spontaneous circulation.

Table 6 Multivariable logistic regression analysis for outcomes of study phase comparing with control phase for the Utstein population with cardiac aetiology, witness status, and shockable rhythm

		Total	Outcome		Model 1			Model 2		
Outcomes	**Group**	**N**	**n**	**%**	**Crude OR**	**95% CI**		**Adjusted OR**	**95% CI**	
Good CPC										
	Control	968	110	11.4	1.00			1.00		
	Phase 1	1115	146	13.1	1.28	0.98	1.68	1.32	1.00	1.75
	Phase 2	3960	1439	36.3	5.31	4.28	6.60	5.76	4.56	7.28
Survival to discharge										
	Control	968	222	22.9	1.00			1.00		
	Phase 1	1115	271	24.3	1.17	0.95	1.44	1.22	0.98	1.51
	Phase 2	3960	1799	45.4	3.28	2.76	3.89	3.79	3.14	4.58
Prehospital ROSC										
	Control	968	53	5.5	1.00			1.00		
	Phase 1	1115	64	5.7	1.12	0.77	1.63	1.09	0.74	1.60
	Phase 2	3960	1781	45.0	16.51	12.38	22.02	14.36	10.66	19.36

Good CPC: cerebral performance scale 1 or 2.
Model 1: adjusted for implemented guideline, gender, age group, metropolis, place of the event, witness, primary ECG, date and time of event (season, weekend, hour).
Model 2: adjusted for implemented guideline, gender, age group, metropolis, place of the event, witness, primary ECG, date and time of event (season, weekend, hour), level of emergency medical technician, number of ambulance crew, response time interval, scene time interval, transport time interval, airway management method, level of emergency department transported to.
AOR, adjusted odd ratio; 95% CI, 95% confidence interval; ROSC, return of spontaneous circulation.

resuscitation attempted OHCA between 2001 and 2010 in the nationwide Danish Cardiac Arrest Registry (n=19 468 showed the significant increase in bystander CPR rate (21.1% in 2001 to 44.9% 2010) and increase in survival on hospital arrival (7.9% in 2001 to 21.8% in 2010), and finally improvement in 30 days survival (3.5% in 2001 to 10.8% in 2010) and 1 year survival (2.9% in 2001 to 10.2% in 2010) (All p-values<0.001). Although the study did not analyse the association between the phase of the national initiatives or implementation of CPR programs and outcome, the findings were very similar to those of our study.

During the ten-year study period, the risk factors were influenced by natural changes in characteristics or by the interventions. To compare the risk factors and outcomes among countries, regions, and local communities and to monitor the trends by year, we need a novel OHCA registry based on a standard report form that includes demographic, system-related, EMS-related, and hospital-related information.[16 17] There may be huge variations in outcomes in different communities due to resources, policies, and system efforts during a long study period.[18–20] One of the issues related to variations in outcomes is the selection bias of denominators and numerators, which can be calculated with different study population criteria.[21] To select a study population as a denominator, an EMS-assessed or EMS-treated population would be standardised to determine incidence and trends in general outcomes. To measure the effect size of the intervention, the Utstein criteria, including witnessed events and shockable rhythm, are recommended.[16 22] Risk factors would be different in different populations, such as in older patients.[23] To compare the outcomes among communities in the observed time intervals, we used age- and gender-adjusted survival rates as well as Utstein survival rates instead of crude survival rates.[9 18 19]

Korea has collected OHCA data for the last ten years and reported the risk factors and outcomes to the public.[9 10] There were multiple national-level interventions derived and implemented by the national government and individual-level interventions accepted and practiced by academic societies and hospitals according to international guidelines.[8 17] The country experienced a rapid increase in population age and change in EMS protocols for selecting patients or time intervals for providing CPR in the field, which may influence the calculated outcome rates.[3 9 24] For the study period, we observed changes in both favourable and unfavourable risk factors. Characteristics of the natural population of OHCA patients that were associated with poor outcomes included increases in the elderly and in female patients,[25–27] increase in response time,[3 28] private location of OHCA,[3 10] and unwitnessed OHCA.[9 10] These risks are related to ageing of the population. However, several favourable factors also increased, such as bystander CPR,[3 19 29] shockable rhythm,[3 10 19] scene time interval,[24] number of EMTs in the ambulance and level of the top EMT. Advanced life support techniques, such as advanced airway management, increased, though the effect of advanced life support techniques on outcomes is controversial.[30 31]

Primary intervention programs, such as system monitoring using a nationwide OHCA registry, followed by EMS CPR registry and dispatch registry, might encourage health policy makers to develop programs to improve outcomes after OHCA. The media reported the nationwide outcomes in 2009 and deeply analysed the causes of poor outcomes and regional variation and provided solutions to improve outcomes. Due to active media coverage, the budget was increased to fund CPR training for lay persons. The OHCA registry enabled monitoring of the various components and revealed weaknesses that led to poorer outcomes.[3 18 19 28 32]

The one of the secondary interventions was the telephone-assisted CPR programme, and it was reported to have strong effects.[10] This programme involved strong education and quality assurance programs. Dispatch-assisted CPR rates quickly increased in up to 50% of all detected OHCAs. The comprehensive medical oversight programme was implemented by the Rescue and EMS Act. In this programme, every EMS agency under a fire department was directed to employ a medical director at least part-time and to provide a full range of information on CPR performance of the EMS crew, including an EMS CPR registry and ECG rhythm analysis.

The prehospital ROSC was higher than survival to discharge rate in 2015. The survival to discharge rate was not increased than 2014, while the good neurological recovery rates and prehospital ROSC rates continuously increased. Increase in bystander CPR might contribute the continuous improvement in prehospital ROSC and good brain recovery. Bystander CPR had interaction with study phases for the outcomes. During the study period, the percentage of patients who received bystander CPR increased continuously. Thus, study phases were interactively related with bystander CPR. In terms of good CPC, the sizes of the effects of phases 1 and 2 were significantly greater in patients who received bystander CPR.

From the sensitivity analysis on Utstein OHCA population whose proportion was 4.6% of original study population, we found the similar effect of Utstein ten-steps CPR programs on outcomes according to phases. The good neurological recovery was significantly improved in both phase 1 and phase 2, and survival to discharge and prehospital ROSC was significantly improved in phase 2. The results were similar to those of original OHCA population.

Limitations

The first limitation is the definition of intervention used in this study. The study intervention was operationally defined based on expert consensus. This method could cause measurement bias, resulting in differences when the programme is fully implemented on a larger scale. Potential interventions were selected from the Utstein Ten-step Implementation Strategy programme, and final interventions were enforced by government acts.

The second limitation is the exclusion criteria, including unknown outcomes, paediatric patients and non-cardiac aetiology. Therefore, the results of this study should only be interpreted in the context of the groups of patients enrolled.

The third limitation is related to the study setting. In Korea, the emergency services are intermediate, which is very different from the advanced services provided in some communities in North America or Europe. Thus, one should be cautious with respect to generalizability.

CONCLUSION

Implementation of national OHCA registry, regular public reports, mandatory CPR training programme, telephone-assisted CPR programme, and medical oversight for EMS CPR performance, which are recommended by the Global Resuscitation Alliance, were significantly associated with better outcomes in the 10 years of before-and after-study in Korea.

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