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Effect of National Implementation of Utstein Ten-step Cardiopulmonary Resuscitation Programs on Outcomes of Out-of-Hospital Cardiac Arrest: A Ten-Year Observational Study

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7. Keywords

Out-of-hospital cardiac arrest, Cardiopulmonary resuscitation, National health policy, Outcomes

Abstract

Objectives

The Utstein ten-step implementation strategy (UTIS), a bundle of public cardiopulmonary resuscitation (CPR) programs to improve outcomes after out-of-hospital cardiac arrests (OHCAs), has been developed. However it is unclear whether UTIS programs are associated with better outcomes or not.

Methods

The study was a before- and after-intervention study. Adults OHCAs treated by emergency medical service (EMS) from 2006 to 2015 were collected, excluding patients collapsed in ambulance and without outcomes. Phase 1(2009-2011) after (1) national OHCA registry, (2) obligatory CPR education, and (3) public report of OHCA, and phase 2(2012-2015) after (4) telephone CPR and (5) comprehensive EMS quality assurance program were compared with the control period (2006-2008). 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 128,888 eligible patients were analyzed. The control, phase 1, and phase 2 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 2.22 (1.91-2.59) for phase 1 and 3.32 (2.87-3.84) for phase 2.

Conclusion

The national implementation of the UTIS programs was significantly associated with better OHCA outcomes.

Article summary

Strengths and limitations of this study

1. The Utstein 10-steps of CPR programs, new concept of implementation strategy, were evaluated for the effect on the outcomes after OHCA. Of 10 steps, (1) national OHCA registry, (2) obligatory CPR education, (3) public report of OHCA, (4) telephone CPR, and (5) comprehensive EMS quality assurance program were implemented in the study setting. The each implementation steps were associated with better outcomes.
2. The study analyzed the 10-years consecutive observations using a national out-of-hospital cardiac arrest registry between before- and after-implementation of CPR programs. The study covers the whole country where the CPR programs were mandatory implemented rather than selectively.
3. Implementation was defined as a program was enacted or started. But the degree of implementation or real change by implementation was not fully measured. This might be related with measurement bias
4. 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.
5. Emergency medical services with low service level were different from North America or European countries where advanced life support are given to OHCA at the field. Therefore the generalization should be cautious.

Effect of National Implementation of Utstein Ten-step Cardiopulmonary Resuscitation Programs on Outcomes of Out-of-Hospital Cardiac Arrest: A Ten-Year Observational Study

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 behavioral barriers.

The Utstein Implementation Meeting was held in 2015 in Stavanger, Norway to discuss ways to implement scientific recommendations at the community level. The result of this meeting was the Utstein Ten-step Implementation Strategy (UTIS) for improving cardiac arrest survival". (See the http://www.resuscitationacademy.org/wp-content/uploads/2016/03/A-Call-to-Establish-a-Global-Resuscitation-Alliance1.pdf). The report from the meeting recommended the followings steps derived from expert consensus: 1) Cardiac arrest registry, 2) Telephone CPR, 3) High-performance CPR, 4) Rapid dispatch, 5) Measurement of professional resuscitation, 6) Automatic external defibrillator (AED) program for first responders, 7) Smart technologies for CPR and AED, 8) Mandatory training for CPR and AED, 9) Accountability, and 10) Culture of excellence.

The UTIS was derived from many studies and experiences in different communities. However, the extent of the impact of implementing the UTIS CPR program 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 Centers 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 km² area of land, where there were multiple regional and local government / hospital organizations: in 2015, there were 17 provinces and 253 local health departments (including 253 local health centers), 17 provincial fire departments, 200 local EMS agencies (966 ambulance stations and 1282 ambulances), and 546 emergency departments (EDs) (20 level 1 regional EDs, 2 specialty EDs, 124 level 2 local EDs, 274 level 3 emergency rooms, and 126 level 4 non-designated urgent facilities). (Available at http:// http://www.e-gen.or.kr/nemc/statistics_annual_report.do and https://www.mpss.go.kr/home/policy/statistics/statisticsData/)

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

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. (9-12) 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 program. 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 program. 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 etiology 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 program was or was not implemented in a community, each program 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 CPR (2011) 3) High performance CPR program (not implemented), 4) Rapid dispatch (2015), 5) Measurement of professional resuscitation (not implemented), 6) AED program for first responders (not implemented), 7) Smart technology for CPR and AED (not implemented), 8)

Mandatory training program for CPR and AED (2008). 9) Accountability (2008), and 10) Cultural excellence (2011). We defined the intervention year as one 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 CPR program 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 program 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 three 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 organizations. The cultural excellence in CPR program 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 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 program and Cultural excellence, including EMS quality assurance programs (Figure 1).

Data variables

We selected several potential confounders for outcomes. These confounders included age, gender, urbanization level (metropolitan city>1 million population, urban/suburban city>50000 population, and rural< 50000 per county), place of the event (public, private, unknown), event witness (witnessed,

unwitnessed), bystander CPR (yes or no), bystander defibrillation (yes or no), dispatcher 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 program.

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. Potential risk factors were tested for trends by year. We tested the trend for age- and gender-standardized outcomes using the whole study population as a standard population.

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, urbanization 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), and level of ED (level 1 to 4) for all patients.

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.

RESULTS

Demographics

Of 229,361 OHCAs during the study period, a total of 128,888 eligible patients were analyzed, excluding patients who were less than age 15 (n=4,478), 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). (Fig. 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 <.001). Patients included in Phases 1 and 2 had much better outcomes than those in the control phase (all p values <.001).

Trend analysis

Fig. 3 shows trends in bystander CPR, pre-hospital ROSC, survival to discharge, and good neurological recovery. There were significant changes from 2006 to 2015 in bystander CPR (1.2% in 2006 versus 16.4% in 2016), pre-hospital ROSC (0.8% in 2006 versus 7.1% in 2015), survival to discharge (3.0% in 2006 versus 6.1% in 2015), and good neurological recovery (1.2% in 2006 versus 4.1% in 2015). (p for trend <.001)

The age-and gender-standardized survival rates (SSRs) were calculated using a direct standardization that used the whole OHCA population during study period as a reference population (Table 2). SSRs

were 2.6 in 2006 versus 6.9 in 2015 per 100 OHCA person-years. SSRs with good neurological recovery were 0.8 in 2006 versus 4.7 in 2015 per 100 OHCA person-years.

Table 3 shows the trend of risk factors stratified by year. Metropolitan locations, season and weekend were not significantly changed by year (p for trend >0.001). The proportions of women and elderly patients, private places, and unwitnessed OHCAs, as well as shorter response time intervals (4 min.), were increased (p for trend <.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 <.001) and were correlated with better outcomes.

Multivariate logistic 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 2.22 (1.91-2.59) for phase 1 and 3.32 (2.87-3.84) for phase 2. AORs (95% CI) in model 2 were 1.95 (1.77-2.13) (phase 1) and 2.09 (1.91-2.29) (phase 2) on survival to discharge and 2.84 (2.44-3.31) (phase 1) and 5.83 (5.06-6.73) (phase 2) on pre-hospital ROSC

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 <.05). There was no significant interaction between pre-hospital ROSC in phases 1 or 2 with bystander CPR (both p values >0.05).

DISCUSSION

During the study period, five programs were implemented, including CPR registry, obligatory CPR

training, and public reports in 2008 and telephone-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.

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. (13, 14) There may be huge variations in outcomes in different communities due to resources, policies, and system efforts during a long study period. (15-17). 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. (18) To select a study population as a denominator, an EMS-assessed or EMS-treated population would be standardized 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. (13, 19) Risk factors would be different in different populations, such as in older patients. (20) 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, 15, 16)

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, 14). 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, 21) For the study period, we observed changes in both favorable and unfavorable 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 (22-24), increase in response time (3, 25), private location of OHCA (3, 10), and unwitnessed OHCA (9, 10). These risks are related to aging of the population. However, several favorable factors also increased, such as bystander CPR (3, 16, 26), shockable rhythm (3, 10, 16), scene time interval (21), 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 (27, 28).

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 analyzed 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, 15, 16, 25, 29).

The one of the secondary interventions wase the telephone CPR program, and it was reported to have strong effects (10). This program 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 program was implemented by the Rescue and EMS Act. In this program, 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.

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.

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 program is fully implemented on a larger scale. Potential interventions were selected from the Utstein Ten-step Implementation Strategy program, and final interventions were enforced by government acts.

The second limitation is the exclusion criteria, including unknown outcomes, pediatric patients and non-cardiac etiology. 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 services provided in North America or Europe. Thus, one should be cautious with respect to generalizability.

COCLUSION

Community interventions, including the OHCA registry, regular public reports, mandatory CPR training programs, telephone CPR program, and medical oversight for EMS CPR performance, which are recommended by the Utstein Ten-steps Implementation Strategy for improving outcomes of OHCA, were significantly associated with better outcomes.

Contributorship statement

Kim YT has developed the data collection system and leaded the public health program. Dr. Kim developed the idea of this paper and wrote the draft. Drs. Song KJ, Ro YS, Ahn KO, and Hong KJ collected the data and contributed the quality management. Dr. Hong SO collected raw data and maintain the quality via education and training the study coordinators. Dr. Shin SD has the full responsibility of the paper. All authors are accessible to the data and agreed with submission of this manuscript to the journal.

Competing interests

No conflicts of interest are associated with this study.

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Data sharing statement

The Korea Centers for Disease Control and Prevention owns the whole data which are accessible to. If a researcher wants to use the data, the researcher should get a permission for the use of the data.

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FIGURE LEGENDS

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 CPR

OA: quality assurance

OHCA: out-of-hospital cardiac arrest

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

Variables		All		Control		Phase 1		Phase 2		P-value
		N	%	N	%	N	%	N	%	
Total		128888	100.0	25045	100.0	39366	100.0	64477	100.0	
Age										<.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										<.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										<.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										<.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										<.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										<.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										<.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	
	DEC-FEB	45993	35.7	8851	35.3	13847	35.2	23295	36.1	
Weekend										<.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										<.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										<.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										<.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)		
Transport time interval										<.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										<.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										<.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	<.001
	Survival to discharge	6621	5.1	851	3.4	1908	4.8	3862	6.0	<.001
	Good CPC	3200	2.5	287	1.1	682	1.7	2231	3.5	<.001

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

Table 2 Age- and gender-standardized rates by year

Year	Total	Survival to discharge					Good CPC				
	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-standardized survival rate

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	128888	6677	7525	10843	11963	13472	13931	14326	15567	16923	17661	
Age												<.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												<.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												<.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												<.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												<.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												<.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	
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													<.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													<.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													<.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													<.001
	0-3 min.	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	
Transport time interval													<.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													<.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													<.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 or Mantel-Haenszel Chi-square test.

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

Outcomes	Group	Total	Outcome		Model 1			Model 2		
		N	n	%	AOR	95% CI		AOR	95% CI	
Good CPC										
	Control	25045	287	1.1	1.00			1.00		
	Phase 1	39366	682	1.7	2.11	1.82	2.45	2.22	1.91	2.59
	Phase 2	64477	2231	3.5	3.13	2.74	3.58	3.32	2.87	3.84
Survival to discharge										
	Control	25045	851	3.4	1.00			1.00		
	Phase 1	39366	1908	4.8	1.85	1.70	2.03	1.95	1.77	2.13
	Phase 2	64477	3862	6.0	1.87	1.72	2.03	2.09	1.91	2.29
Prehospital ROSC										
	Control	25045	243	1.0	1.00			1.00		
	Phase 1	39366	837	2.1	2.84	2.45	3.29	2.84	2.44	3.31
	Phase 2	64477	3642	5.6	6.54	5.71	7.49	5.83	5.06	6.73

AOR: adjusted odd ratio, 95% CI: 95% confidence interval

Good CPC: cerebral performance scale 1 or 2

ROSC: return of spontaneous circulation

Model 1: adjusted for gender, age group, metropolis, place of the event, witness, primary ECG, date and time of event (season, weekend, hour).

Model 2: adjusted for 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..

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

Outcome	Group	Bystander CPR (-)			Bystander CPR (+)			P value for interaction
		AOR	95% CI		AOR	95% CI		
Good CPC								
	Control	1.00			1.00			
	Phase 1	1.93	1.64	2.26	4.41	2.49	7.81	0.006
	Phase 2	2.67	2.30	3.11	5.27	3.06	9.08	0.018
Survival to discharge								
	Control	1.00			1.00			
	Phase 1	1.82	1.65	2.00	2.81	1.91	4.14	0.032
	Phase 2	1.82	1.66	2.01	2.64	1.83	3.80	0.054
Prehospital ROSC								
	Control	1.00			1.00			
	Phase 1	2.57	2.19	3.01	4.05	2.31	7.10	0.124
	Phase 2	5.27	4.54	6.11	5.59	3.27	9.57	0.831

AOR: adjusted odd ratio, 95% CI: 95% confidence interval

Good CPC: cerebral performance scale 1 or 2

ROSC: return of spontaneous circulation

Adjusted for 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).

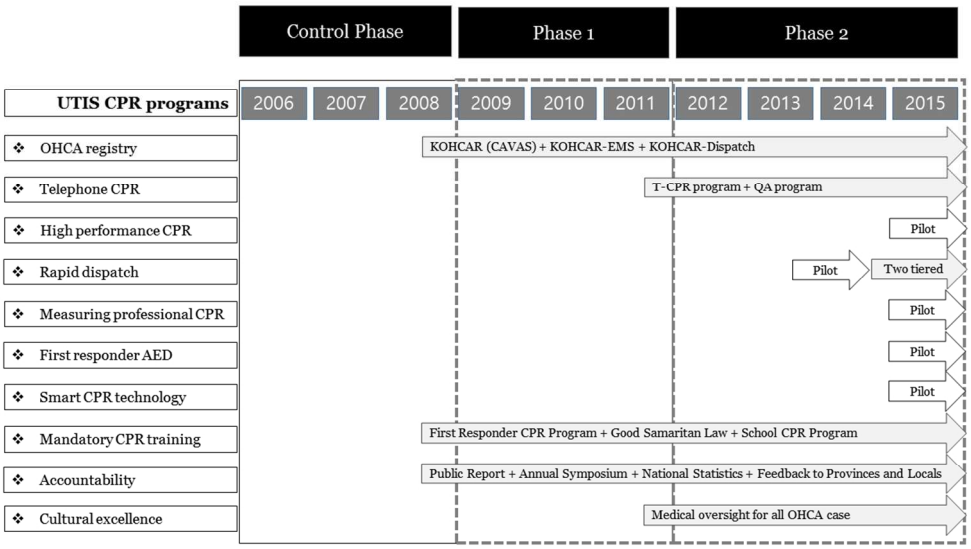

Figure 1 National Implementation of Utstein Ten-step Implementation Strategy by study period
CPR: cardiopulmonary resuscitation
AED: automatic external defibrillation
KOHCAR: Korea out-of-hospital cardiac arrest registry
EMS: emergency medical services
T-CPR: telephone CPR
OA: quality assurance
OHCA: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

338x190mm (96 x 96 DPI)

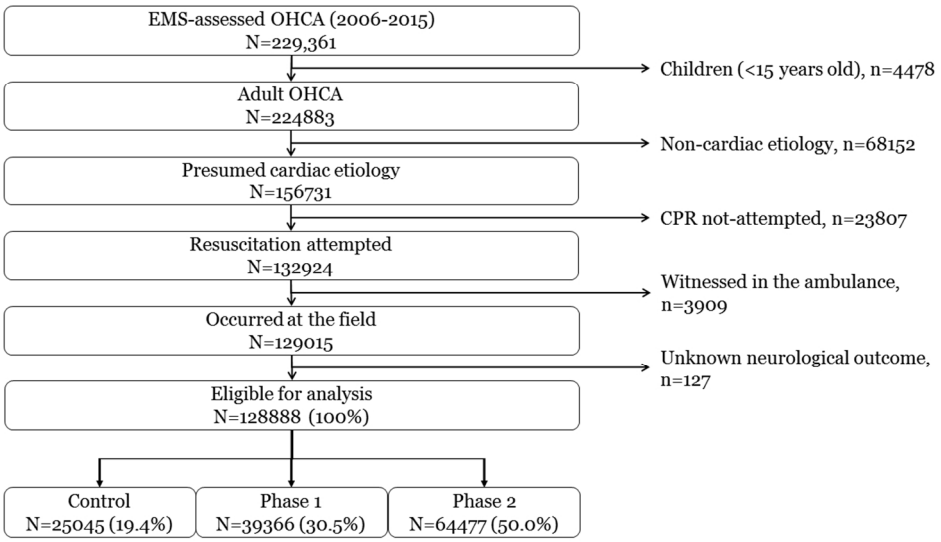

Figure 2 Study subjects
EMS: emergency medical service
OHCA: out-of-hospital cardiac arrest
CPR: cardiopulmonary resuscitation

338x190mm (96 x 96 DPI)

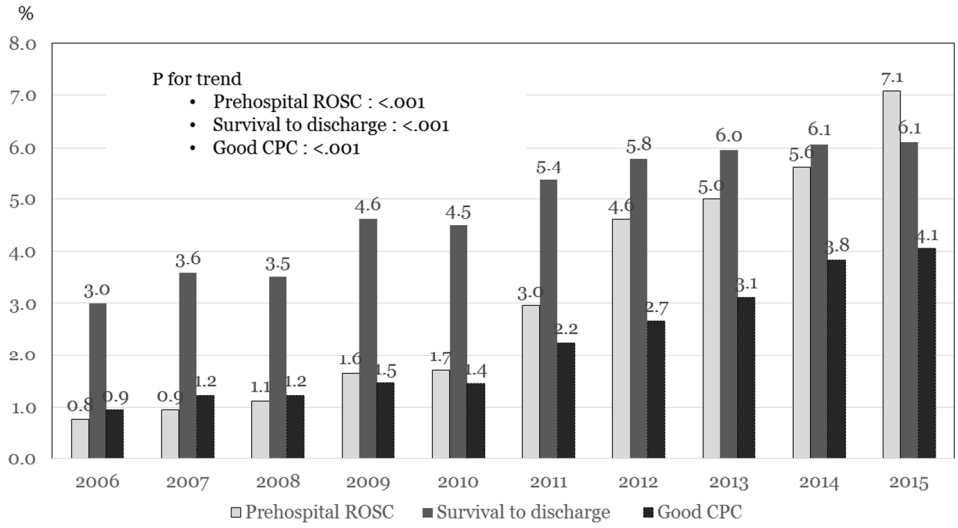

Figure 3 Longitudinal trend of outcomes in out-of-hospital cardiac arrest in Korea
ROSC: return of spontaneous circulation
CPC: cerebral performance scale

338x190mm (96 x 96 DPI)

Appendix 1. Utstein ten-steps implementation strategy (UTIS)

Step 1. Do you have a **community-based cardiac arrest registry**?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

- ☐ Minimal status is defined as the registry has *NEITHER* quality assurance program *NOR* sufficient information on 2014 Utstein template information
- ☐ Moderate status is defined as the registry has *EITHER* quality assurance program *OR* sufficient information on 2014 Utstein template information
- ☐ Full status is defined as the registry has *BOTH* quality assurance program *AND* sufficient information on 2014 Utstein template information

Notes:

※ Community-based cardiac arrest registry means that the registry has been continuously maintained with regularity and basic information on OHCA and CPR covering the whole community.

※ Quality assurance program includes 1) standard data dictionary for the variables 2) regular data quality management and 3) education and training for data coordinator and providers.

※ Sufficient information on 2014 Utstein template includes the registry has most factors on system, individual, structure, process, and outcomes.

Step 2. Do you have a **telephone CPR program**?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

- ☐ Minimal status is defined as the registry has *NEITHER* quality assurance program *NOR* telephone CPR registry
- ☐ Moderate status is defined as the registry has *EITHER* quality assurance program *OR* telephone CPR registry
- ☐ Full status is defined as the registry has *BOTH* quality assurance program *AND* telephone

CPR registry

Notes

※ Telephone CPR program means that a community dispatch center provides dispatcher-assisted CPR instruction program when a call is recognized as a case of cardiac arrest.

※ Quality assurance program includes 1) dispatch protocol, 2) dispatcher training, 3) audio-tape review and feedback.

※ Telephone CPR registry includes the caller information, dispatch time variable, process variable, and CPR instruction.

Step 3. Do you have a **high performance CPR program**?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

- ☐ Minimal status is defined as the registry has *NEITHER* high performance CPR training program *NOR* quality assurance program using an objective measurement tool.
- ☐ Moderate status is defined as the registry has *EITHER* high performance CPR training program *NOR* quality assurance program using an objective measurement tool.
- ☐ Full status is defined as the registry has *BOTH* high performance CPR training program *AND* quality assurance program using an objective measurement tool.

Notes

※ High performance (HP) CPR program means that the community encourages providers to perform HP CPR on 1) correct hand position, 2) compression rate of 100-120 beats per minute, 3) depth of compression of 2 inches (5-6 cm), 4) full recoil on the upstroke, 5) 50:50 duty cycles, 6) ventilations of one second each, 7) minimal interruptions of CPR (no pause to exceed 10 seconds), and 8) intubation and IV start without pausing chest compressions.

※ High performance CPR training includes the system provides a special education and team training with providers regularly.

※ Quality assurance program includes the regular review of team CPR and get feedback to providers.

Step 4. Do you have a **rapid dispatch program**?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

☐ Minimal status is defined as the rapid dispatch program has *NEITHER* rapid dispatch indication and protocol *NOR* quality assurance program.

☐ Moderate status is defined as the rapid dispatch program has *EITHER* rapid dispatch indication and protocol *OR* quality assurance program.

☐ Full status is defined as the rapid dispatch program has *BOTH* rapid dispatch indication and protocol *AND* quality assurance program.

Notes

※ Rapid dispatch program means that the community sends available vehicles and services responding to OHCA quickly within a critical time interval (such as 60 seconds)

※ Rapid dispatch indication and protocol includes target emergency condition and dispatch protocol for available vehicles and providers such as tiered response to shorten the time process.

※ Quality assurance program includes the regular training and education of dispatcher, regular review of dispatch record, and on-going feedback to the providers.

Step 5. Do you have a **measurement program of professional resuscitation** using high technology device?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

☐ Minimal status is defined as the professional CPR measurement has *NEITHER* high technology devices *NOR* quality assurance program.

☐ Moderate status is defined as the professional CPR measurement has *EITHER* high technology devices *OR* quality assurance program.

☐ Full status is defined as the professional CPR measurement has *BOTH* high technology

devices *AND* quality assurance program.

Notes

※ The professional CPR measurement means that the providers use the high technology defibrillator devices which can provide information on a full range of CPR quality.

※ High technology devices include function of measuring depth, rate, pause, no-flow time objectively and continuously and function for audio-recording system, memory, and data downloading.

※ Quality assurance program includes the data collection from devices, analysis, providing feedback with providers, regularly.

Step 6. Do you have a **first responder (policemen or safety guards) AED program**?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

☐ Minimal status is defined as the first responder AED program has *NEITHER* education and training on first responder AED *NOR* quality assurance program of first responder defibrillation.

☐ Moderate status is defined as the first responder AED program has *EITHER* education and training on first responder AED *OR* quality assurance program of first responder defibrillation.

☐ Full status is defined as the first responder AED program has *BOTH* education and training on first responder AED *AND* quality assurance program of first responder defibrillation.

Notes

※ The first responder AED program means that the community encourages policemen or safety guards to use AED by law or voluntary-based.

※ The first responder AED training/ education includes a regular education and training program on AED use and response for police and safety guards.

※ Quality assurance program includes the data collection from devices and analysis of first responder AED use and providing feedback with the first responders, regularly.

Step 7. Do you use **a smart technology to activate layperson to provide CPR and use public access defibrillator (PAD)**?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

☐ Minimal status is defined as smart technology program for CPR and PAD has *NEITHER* an advanced technology for geographical information *NOR* an activation program for layperson CPR and PAD.

☐ Moderate status is defined as smart technology program for CPR and PAD has *EITHER* an advanced technology for geographical information *OR* an activation program for layperson CPR and PAD.

☐ Full status is defined as smart technology program for CPR and PAD has *BOTH* an advanced technology for geographical information *AND* an activation program for layperson CPR and PAD.

Notes

※ Smart technology program for CPR and PAD means that the community has program activate lay person to provide CPR and defibrillation using PAD via geographic information and activation program of layperson volunteer.

※ An advanced technology for geographical information includes special geographic information technology to let layperson identify the location of OHCA and the nearest PAD.

※ The activation of layperson for CPR and PAD includes the dispatch centers activate layperson volunteer for providing CPR and defibrillation with OHCA located in the nearest area.

Step 8. Do you have a **mandatory CPR training** in schools and other community areas in addition to first responders?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

☐ Minimal status is defined as the mandatory CPR training covers *NEITHER* school *NOR* the other areas such as driver license applicants.

- ☐ Moderate status is defined as the mandatory CPR training covers *EITHER* school *OR* the other areas such as driver license applicants.
- ☐ Full status is defined as the mandatory CPR training covers *BOTH* school *AND* the other areas such as driver license applicants.

Notes

※ The mandatory CPR training means the community has law for obligatory CPR training in schools and other areas such as driver license applicants.

※ The mandatory school CPR includes regular program for CPR training for students and teachers based on an Act, Law, or Regulation.

※ The mandatory training program for other areas includes obligatory training for driver license applicants.

Step 9. Do you think your community has an **accountability on OHCA and CPR** outcomes?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

- ☐ Minimal status is defined when *NEITHER* the community reports OHCA information and CPR outcomes to the public annually *NOR* the community organizations share the information sufficiently.
- ☐ Moderate status is defined when *EITHER* the community reports OHCA information and CPR outcomes to the public annually *OR* the community organizations share the information sufficiently.
- ☐ Full status is defined when *BOTH* the community reports OHCA information and CPR outcomes to the public annually *AND* the community organizations share the information sufficiently.

Notes

※ The accountability on OHCA and CPR outcomes means the community reports OHCA information and CPR outcomes to the public annually and involved organizations share the information sufficiently.

※ Public reports includes the annual incidence, outcomes by rhythms, locations, bystander CPR, PAD use, and response time.

※ Information sharing includes the organizations communicate with each other, and exchange information and data for CPR program.

Step 10. Do you think your community has a **cultural excellence** for improving CPR outcomes?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

☐ Minimal status is defined when *NEITHER* the medical directors play the key role for system development *NOR* host CPR-related meetings regularly.

☐ Moderate status is defined when *EITHER* the medical directors play the key role for system development *OR* host CPR-related meetings regularly.

☐ Full status is defined when *BOTH* the medical directors play the key role for system development *AND* host CPR-related meetings regularly.

Notes

※ The cultural excellence means the medical directors are actively engaged in system development, protocol, education, and quality assurance program and meet with community leaders regularly for communication, collaboration, and coordination to establish the best practice.

※ The role of medical directors includes system development, education and training, certification, and quality assurance program.

※ Leadership meeting indicates the meeting of organization leaders to meet and communicate with each other regularly for improving CPR outcomes.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	P1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	P3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	P5
Objectives	3	State specific objectives, including any prespecified hypotheses	P5
Methods			
Study design	4	Present key elements of study design early in the paper	P5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	P6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	P7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	P8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*P6*
Bias	9	Describe any efforts to address potential sources of bias	P8
Study size	10	Explain how the study size was arrived at	P9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	P9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	P9
		(*b*) Describe any methods used to examine subgroups and interactions	P9
		(*c*) Explain how missing data were addressed	P9
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	P9
		(*e*) Describe any sensitivity analyses	

Continued on next page

Results			**Page**
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	P10
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	Fig 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	P10 Table 1
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	P10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	P11
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	P11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	P13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	P12
Generalisability	21	Discuss the generalisability (external validity) of the study results	P13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	P15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

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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Title

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7. Keywords

Out-of-hospital cardiac arrest, Cardiopulmonary resuscitation, National health policy, Outcomes

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 program 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 program) were compared with the control period (2006-2008) when no UTIS program 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 128,888 eligible patients were analyzed. The control, phase 1, and phase 2 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 2 compared with control phase.

Conclusion

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

Article summary

Strengths and limitations of this study

1. 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.
2. 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.
3. 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.
4. 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 generalization should be cautious.

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

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 behavioral 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) program 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 organizations 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 Centers 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 km² area of land, where there were multiple regional and local government / hospital organizations: in 2015, there were 17 provinces and 253 local health departments (including 253 local health centers), 17 provincial fire departments, 200 local EMS agencies (966 ambulance stations and 1282 ambulances), and 546 emergency departments (EDs) (20 level 1 regional EDs, 2 specialty EDs, 124 level 2 local EDs, 274 level 3 emergency rooms, and 126 level 4 non-designated urgent facilities).

The Ministry of Health and Welfare EMS program is responsible for emergency care services, acts and regulations, budgeting and policy planning. The Korea Centers for Disease Control and Prevention (CDC) is responsible for the community CPR program by developing national standards and education programs. The National Medical Center is responsible for hospital-based emergency care through the ED evaluation program 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 program. 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 program. 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 etiology 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 program was or was not implemented in a community, each program 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 program (not implemented), 4) Rapid dispatch (2015), 5) Measurement of professional resuscitation (not implemented), 6) AED program for first responders (not implemented), 7) Smart technology for CPR and AED (not implemented), 8) Mandatory training program for CPR and AED (2008). 9) Accountability (2008), and 10) Cultural excellence (2011). We defined the intervention year as one 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 program 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 program 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 three 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 organizations. The cultural excellence in CPR program 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 program and Cultural excellence, including EMS quality assurance programs (Figure 1).

Data variables

We selected several potential confounders for outcomes. These confounders included age, gender, urbanization level (metropolitan city>1 million population, urban/suburban city>50000 population, and rural< 50000 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 program.

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 100,000 population of each year. The IRs were calculated from the total number of OHCA with all causes in all gender/ age group divided by the total number of population multiplying 100,000. Potential risk factors were tested for trends by year. We tested the trend for age- and gender-standardized 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, urbanization 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 etiology, 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 128,888 eligible patients were analyzed, excluding patients who were less than age 15 (n=4,478), 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). (Fig. 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 <.001). Patients included in Phases 1 and 2 had much better outcomes than those in the control phase (all p values <.001).

Trend analysis

Fig. 3 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 versus 16.4% in 2016), pre-hospital ROSC (0.8% in 2006 versus 7.1% in 2015), survival to discharge (3.0% in 2006 versus 6.1% in 2015), and good neurological recovery (1.2% in 2006 versus 4.1% in 2015). (p for trend <.001) The prehospital ROSC was higher than survival to discharge rate in 2015.

The age-and gender-standardized survival rates (SSRs) were calculated using a direct standardization that used the whole OHCA population during study period as a reference population (Table 2). SSRs were 2.6 in 2006 versus 6.9 in 2015 per 100 OHCA person-years. SSRs with good neurological recovery were 0.8 in 2006 versus 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 <.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 <.001).

Multivariate logistic 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 <.05). There was no significant interaction between pre-hospital ROSC in phases 1 or 2 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 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 resuscitation attempted OHCA between 2001 and 2010 in the nationwide Danish Cardiac Arrest Registry (n=19468 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 < .001). Although the study did not analyze 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 standardized 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 favorable and unfavorable 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 aging of the population. However, several favorable 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 analyzed 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 program, and it was reported to have strong effects (10). This program 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 program was implemented by the Rescue and EMS Act. In this program, 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 program is fully implemented on a larger scale. Potential interventions were selected from the Utstein Ten-step Implementation Strategy program, and final interventions were enforced by government acts.

The second limitation is the exclusion criteria, including unknown outcomes, pediatric patients and non-cardiac etiology. 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 program, telephone-assisted CPR program, 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.

Contributorship statement

Kim YT has developed the data collection system and leaded the public health program. Dr. Kim developed the idea of this paper and wrote the draft. Drs. Song KJ, Ro YS, Ahn KO, and Hong KJ collected the data and contributed the quality management. Dr. Hong SO collected raw data and maintain the quality via education and training the study coordinators. Dr. Shin SD has the full responsibility of the paper. All authors are accessible to the data and agreed with submission of this manuscript to the journal.

Competing interests

No conflicts of interest are associated with this study.

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Data sharing statement

The Korea Centers for Disease Control and Prevention owns the whole data which are accessible to. If a researcher wants to use the data, the researcher should get a permission for the use of the data.

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FIGURE LEGENDS

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

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

Variables		All		Control		Phase 1		Phase 2		P-value
		N	%	N	%	N	%	N	%	
Total		128888	100.0	25045	100.0	39366	100.0	64477	100.0	
Age										<.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										<.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										<.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										<.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										<.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										<.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										<.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	
	DEC-FEB	45993	35.7	8851	35.3	13847	35.2	23295	36.1	
Weekend										<.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									<.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									<.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									<.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)		
Transport time interval									<.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									<.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										<.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	<.001
	Survival to discharge	6621	5.1	851	3.4	1908	4.8	3862	6.0	<.001
	Good CPC	3200	2.5	287	1.1	682	1.7	2231	3.5	<.001

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

Table 2 Age- and gender-standardized rates by year

Year	Total	Survival to discharge					Good CPC				
	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-standardized survival rate

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	128888	6677	7525	10843	11963	13472	13931	14326	15567	16923	17661	
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												<.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												<.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												<.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												<.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												<.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												<.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	
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												<.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												<.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												<.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												<.001
0-3 min.	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	
Transport time interval												<.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												<.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												<.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	Outcome		Model 1			Model 2		
		N	n	%	AOR	95% CI		AOR	95% CI	
Good CPC										
	Control	25045	287	1.1	1.00			1.00		
	Phase 1	39366	682	1.7	1.75	1.48	2.07	1.82	1.53	2.15
	Phase 2	64477	2231	3.5	1.97	1.59	2.43	2.21	1.78	2.75
Survival to discharge										
	Control	25045	851	3.4	1.00			1.00		
	Phase 1	39366	1908	4.8	1.73	1.57	1.90	1.79	1.62	1.98
	Phase 2	64477	3862	6.0	1.54	1.36	1.76	1.78	1.56	2.04
Prehospital ROSC										
	Control	25045	243	1.0	1.00			1.00		
	Phase 1	39366	837	2.1	2.21	1.87	2.60	2.20	1.86	2.59
	Phase 2	64477	3642	5.6	3.58	2.94	4.36	3.47	2.84	4.24

AOR: adjusted odd ratio, 95% CI: 95% confidence interval

Good CPC: cerebral performance scale 1 or 2

ROSC: return of spontaneous circulation

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.

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

Outcome	Group	Bystander CPR (-)			Bystander CPR (+)			P value for interaction
		AOR	95% CI		AOR	95% CI		
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

AOR: adjusted odd ratio, 95% CI: 95% confidence interval

Good CPC: cerebral performance scale 1 or 2

ROSC: return of spontaneous circulation

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).

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

Outcomes	Group	Total	Outcome		Model 1			Model 2		
		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

AOR: adjusted odd ratio, 95% CI: 95% confidence interval

Good CPC: cerebral performance scale 1 or 2

ROSC: return of spontaneous circulation

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.

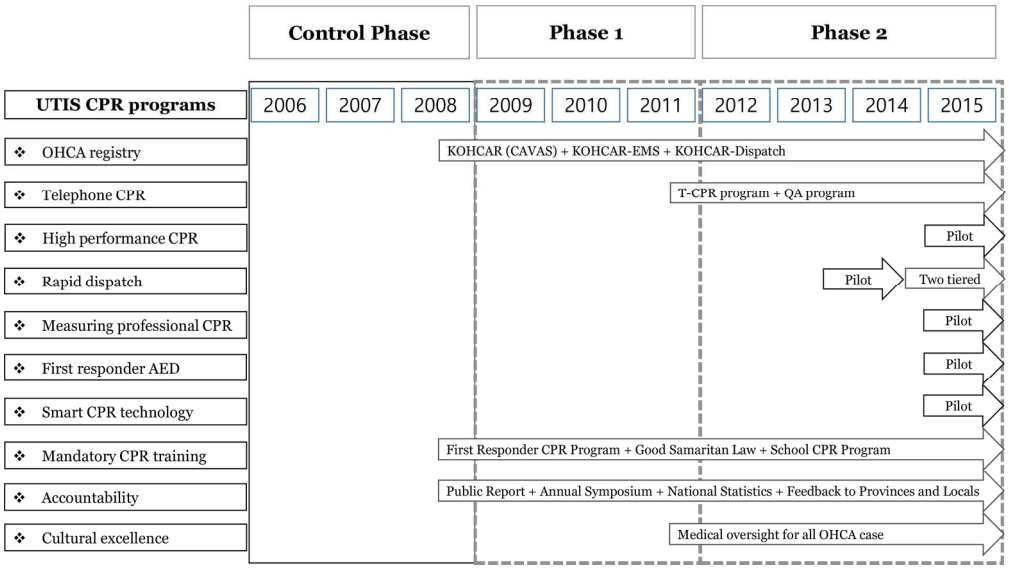

Figure 1 National Implementation of Utstein Ten-step Implementation Strategy by study period
CPR: cardiopulmonary resuscitation
AED: automatic external defibrillation
KOHCAR: Korea out-of-hospital cardiac arrest registry
EMS: emergency medical services
T-CPR: telephone-assisted CPR
OA: quality assurance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

190x106mm (300 x 300 DPI)

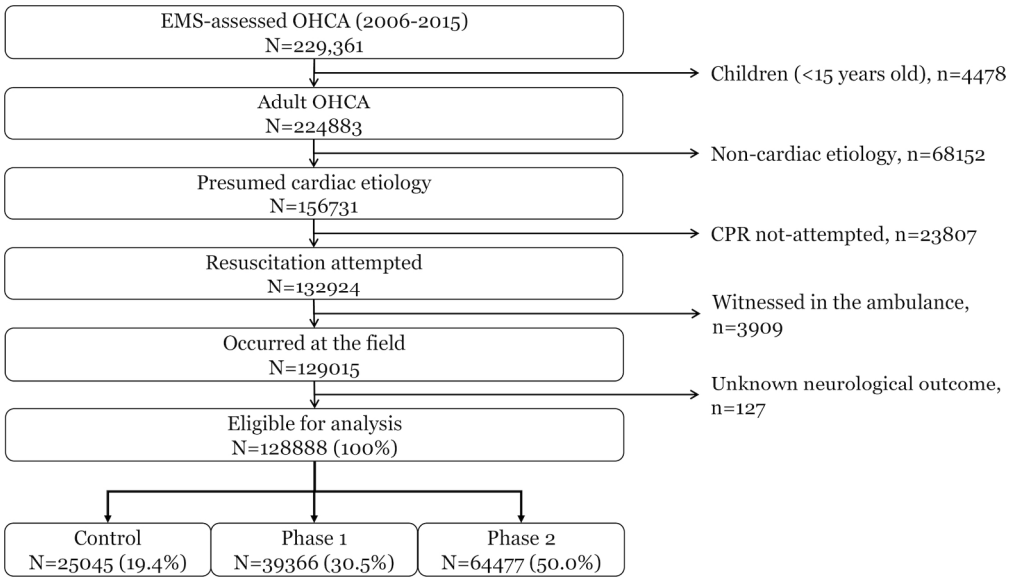

Figure 2 Study subjects
EMS: emergency medical service
OHCA: out-of-hospital cardiac arrest
CPR: cardiopulmonary resuscitation

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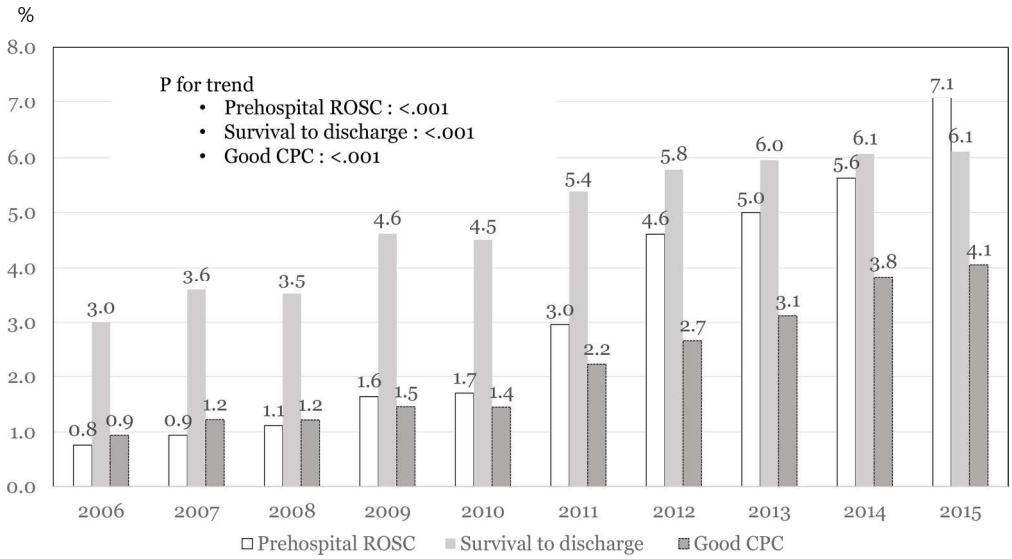

Figure 3 Longitudinal trend of outcomes in out-of-hospital cardiac arrest in Korea
ROSC: return of spontaneous circulation
CPC: cerebral performance scale

190x104mm (300 x 300 DPI)

Appendix 1. Utstein ten-steps implementation strategy (UTIS)

Step 1. Do you have a **community-based cardiac arrest registry**?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

☐ Minimal status is defined as the registry has *NEITHER* quality assurance program *NOR* sufficient information on 2014 Utstein template information

☐ Moderate status is defined as the registry has *EITHER* quality assurance program *OR* sufficient information on 2014 Utstein template information

☐ Full status is defined as the registry has *BOTH* quality assurance program *AND* sufficient information on 2014 Utstein template information

Notes:

※ Community-based cardiac arrest registry means that the registry has been continuously maintained with regularity and basic information on OHCA and CPR covering the whole community.

※ Quality assurance program includes 1) standard data dictionary for the variables 2) regular data quality management and 3) education and training for data coordinator and providers.

※ Sufficient information on 2014 Utstein template includes the registry has most factors on system, individual, structure, process, and outcomes.

Step 2. Do you have a **telephone CPR program**?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

☐ Minimal status is defined as the registry has *NEITHER* quality assurance program *NOR* telephone CPR registry

☐ Moderate status is defined as the registry has *EITHER* quality assurance program *OR* telephone CPR registry

☐ Full status is defined as the registry has *BOTH* quality assurance program *AND* telephone CPR registry

Notes

※ Telephone CPR program means that a community dispatch center provides dispatcher-assisted CPR instruction program when a call is recognized as a case of cardiac arrest.

※ Quality assurance program includes 1) dispatch protocol, 2) dispatcher training, 3) audio-tape review and feedback.

※ Telephone CPR registry includes the caller information, dispatch time variable, process variable, and CPR instruction.

Step 3. Do you have a **high performance CPR program**?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

- ☐ Minimal status is defined as the registry has *NEITHER* high performance CPR training program *NOR* quality assurance program using an objective measurement tool.
- ☐ Moderate status is defined as the registry has *EITHER* high performance CPR training program *NOR* quality assurance program using an objective measurement tool.
- ☐ Full status is defined as the registry has *BOTH* high performance CPR training program *AND* quality assurance program using an objective measurement tool.

Notes

※ High performance (HP) CPR program means that the community encourages providers to perform HP CPR on 1) correct hand position, 2) compression rate of 100-120 beats per minute, 3) depth of compression of 2 inches (5-6 cm), 4) full recoil on the upstroke, 5) 50:50 duty cycles, 6) ventilations of one second each, 7) minimal interruptions of CPR (no pause to exceed 10 seconds), and 8) intubation and IV start without pausing chest compressions.

※ High performance CPR training includes the system provides a special education and team training with providers regularly.

※ Quality assurance program includes the regular review of team CPR and get feedback to providers.

Step 4. Do you have a **rapid dispatch program**?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

- ☐ Minimal status is defined as the rapid dispatch program has *NEITHER* rapid dispatch indication and protocol *NOR* quality assurance program.
- ☐ Moderate status is defined as the rapid dispatch program has *EITHER* rapid dispatch indication and protocol *OR* quality assurance program.
- ☐ Full status is defined as the rapid dispatch program has *BOTH* rapid dispatch indication and protocol *AND* quality assurance program.

Notes

※ Rapid dispatch program means that the community sends available vehicles and services responding to OHCA quickly within a critical time interval (such as 60 seconds)

※ Rapid dispatch indication and protocol includes target emergency condition and dispatch protocol for available vehicles and providers such as tiered response to shorten the time process.

※ Quality assurance program includes the regular training and education of dispatcher, regular review of dispatch record, and on-going feedback to the providers.

Step 5. Do you have a **measurement program of professional resuscitation** using high technology device?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

- ☐ Minimal status is defined as the professional CPR measurement has *NEITHER* high technology devices *NOR* quality assurance program.
- ☐ Moderate status is defined as the professional CPR measurement has *EITHER* high technology devices *OR* quality assurance program.
- ☐ Full status is defined as the professional CPR measurement has *BOTH* high technology devices *AND* quality assurance program.

Notes

※ The professional CPR measurement means that the providers use the high technology defibrillator devices which can provide information on a full range of CPR quality.

※ High technology devices include function of measuring depth, rate, pause, no-flow time objectively and continuously and function for audio-recording system, memory, and data downloading.

※ Quality assurance program includes the data collection from devices, analysis, providing feedback with providers, regularly.

Step 6. Do you have a **first responder (policemen or safety guards) AED program**?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

☐ Minimal status is defined as the first responder AED program has *NEITHER* education and training on first responder AED *NOR* quality assurance program of first responder defibrillation.

☐ Moderate status is defined as the first responder AED program has *EITHER* education and training on first responder AED *OR* quality assurance program of first responder defibrillation.

☐ Full status is defined as the first responder AED program has *BOTH* education and training on first responder AED *AND* quality assurance program of first responder defibrillation.

Notes

※ The first responder AED program means that the community encourages policemen or safety guards to use AED by law or voluntary-based.

※ The first responder AED training/ education includes a regular education and training program on AED use and response for police and safety guards.

※ Quality assurance program includes the data collection from devices and analysis of first responder AED use and providing feedback with the first responders, regularly.

Step 7. Do you use **a smart technology to activate layperson to provide CPR and use public access defibrillator (PAD)**?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

☐ Minimal status is defined as smart technology program for CPR and PAD has *NEITHER* an advanced technology for geographical information *NOR* an activation program for layperson CPR and PAD.

☐ Moderate status is defined as smart technology program for CPR and PAD has *EITHER* an advanced technology for geographical information *OR* an activation program for layperson CPR and PAD.

☐ Full status is defined as smart technology program for CPR and PAD has *BOTH* an advanced technology for geographical information *AND* an activation program for layperson CPR and PAD.

Notes

※ Smart technology program for CPR and PAD means that the community has program activate lay person to provide CPR and defibrillation using PAD via geographic information and activation program of layperson volunteer.

※ An advanced technology for geographical information includes special geographic information technology to let layperson identify the location of OHCA and the nearest PAD.

※ The activation of layperson for CPR and PAD includes the dispatch centers activate layperson volunteer for providing CPR and defibrillation with OHCA located in the nearest area.

Step 8. Do you have a **mandatory CPR training** in schools and other community areas in addition to first responders?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

☐ Minimal status is defined as the mandatory CPR training covers *NEITHER* school *NOR* the other areas such as driver license applicants.

☐ Moderate status is defined as the mandatory CPR training covers *EITHER* school *OR* the other areas such as driver license applicants.

- ☐ Full status is defined as the mandatory CPR training covers *BOTH* school *AND* the other areas such as driver license applicants.

Notes

※ The mandatory CPR training means the community has law for obligatory CPR training in schools and other areas such as driver license applicants.

※ The mandatory school CPR includes regular program for CPR training for students and teachers based on an Act, Law, or Regulation.

※ The mandatory training program for other areas includes obligatory training for driver license applicants.

Step 9. Do you think your community has an **accountability on OHCA and CPR** outcomes?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

- ☐ Minimal status is defined when *NEITHER* the community reports OHCA information and CPR outcomes to the public annually *NOR* the community organizations share the information sufficiently.
- ☐ Moderate status is defined when *EITHER* the community reports OHCA information and CPR outcomes to the public annually *OR* the community organizations share the information sufficiently.
- ☐ Full status is defined when *BOTH* the community reports OHCA information and CPR outcomes to the public annually *AND* the community organizations share the information sufficiently.

Notes

※ The accountability on OHCA and CPR outcomes means the community reports OHCA information and CPR outcomes to the public annually and involved organizations share the information sufficiently.

※ Public reports includes the annual incidence, outcomes by rhythms, locations, bystander CPR, PAD use, and response time.

※ Information sharing includes the organizations communicate with each other, and exchange information and data for CPR program.

Step 10. Do you think your community has a **cultural excellence** for improving CPR outcomes?

☐ No

☐ Yes, started in (□□□□)

If yes, please check the implementation status according to the notes below:

☐ Minimal status is defined when *NEITHER* the medical directors play the key role for system development *NOR* host CPR-related meetings regularly.

☐ Moderate status is defined when *EITHER* the medical directors play the key role for system development *OR* host CPR-related meetings regularly.

☐ Full status is defined when *BOTH* the medical directors play the key role for system development *AND* host CPR-related meetings regularly.

Notes

※ The cultural excellence means the medical directors are actively engaged in system development, protocol, education, and quality assurance program and meet with community leaders regularly for communication, collaboration, and coordination to establish the best practice.

※ The role of medical directors includes system development, education and training, certification, and quality assurance program.

※ Leadership meeting indicates the meeting of organization leaders to meet and communicate with each other regularly for improving CPR outcomes.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	P1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	P3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	P5
Objectives	3	State specific objectives, including any prespecified hypotheses	P5
Methods			
Study design	4	Present key elements of study design early in the paper	P5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	P6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	P7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	P8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*P6*
Bias	9	Describe any efforts to address potential sources of bias	P8
Study size	10	Explain how the study size was arrived at	P9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	P9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	P9
		(*b*) Describe any methods used to examine subgroups and interactions	P9
		(*c*) Explain how missing data were addressed	P9
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	P9
		(*e*) Describe any sensitivity analyses	

Continued on next page

Results			**Page**
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	P10
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	Fig 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	P10 Table 1
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	P10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	P11
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	P11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	P13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	P12
Generalisability	21	Discuss the generalisability (external validity) of the study results	P13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	P15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.