ORIGINAL RESEARCH

Application of the "Plan-Do-Study-Act" Model to Improve Survival after Cardiac Arrest in Korea: A Case Study

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Abbreviations:
CPR: cardiopulmonary resuscitation
ED: emergency department
EMS: Emergency Medical Services
EMT: emergency medical technician
OHCA: out-of-hospital cardiac arrest
PCI: percutaneous coronary intervention
PDSA: Plan-Do-Study-Act
QI: quality improvement
ROSC: return of spontaneous circulation
TTM: targeted temperature management

Abstract

Objective: Low rates of bystander cardiopulmonary resuscitation (CPR) were identified as a shortcoming in the "chain of survival" for out-of-hospital cardiac arrest (OHCA) care in the Korean city of Ansan. This study sought to evaluate the effect of an initiative to increase bystander CPR and quality of out-of-hospital resuscitation on outcome from OHCA. The post-intervention data were used to determine the next quality improvement (QI) target as part of the "Plan-Do-Study-Act" (PDSA) model for QI.

Hypothesis: The study hypothesis was that bystander CPR, return of spontaneous circulation (ROSC), and survival to discharge after OHCA would increase in the post-intervention period.

Methods: This was a retrospective pre/post study. The data from the pre-intervention period were abstracted from 2008–2011 and the post-intervention period from 2012–2013. The effect of the intervention on the odds of ROSC and survival to hospital discharge was determined using a generalized estimating equation to account for confounders and the effect of clustering within medical centers. The analysis was then used to identify other factors associated with outcomes to determine the next targets for intervention in the chain of survival for cardiac arrest in this community.

Results: Rates of documented bystander CPR increased from 13% in the pre-intervention period to 37% in the post-intervention period. The overall rate of ROSC decreased from 18.4% to 14.3% (risk difference −4.1%; 95% CI, −7.1%–1.0%), whereas survival to hospital discharge increased from 3.9% to 5.0% (risk difference 1.1%; 95% CI, −1.8%–3.8%), and survival with good neurologic outcome increased from 0.8% to 1.6% (risk difference 0.8%; 95% CI, −0.8%–2.4%). In multivariable analyses, there was no association between the intervention and the rate of ROSC or survival to hospital discharge. The designated level of the treating hospital was a significant predictor of both survival and ROSC.

Conclusion: In this case study, there were no observed improvements in outcomes from OHCA after the targeted intervention to improve out-of-hospital CPR. However, utilizing the PDSA model for QI, the designated level of the treating hospital was found to be a significant predictor of survival in the post-period, identifying the next target for intervention.

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Introduction

Despite wide-spread adoption of the "chain of survival" for optimization of cardiac arrest outcomes, survival after out-of-hospital cardiac arrest (OHCA) varies widely both by country and by region within countries. In Korea, the overall survival rate for OHCA from 2006 to 2010 was 3.0%,[1] less than one-third of the 9.6% overall survival rate reported by the United States Centers for Disease Control and Prevention (CDC; Atlanta, Georgia USA),[2] but within the range of regional variation from 3.0% to 16.3% reported in North America.[3] Survival rates also vary in Korea by administrative district, with rates as low as 0.8% in some districts.[1]

Regional variation can be attributed to the strength and quality of each link in the chain of survival within communities.[4] Individual Emergency Medical Services (EMS) systems must analyze the weak links in their chain of survival, implement an intervention for quality improvement (QI), study the effect of the intervention, and then act upon the next weak link identified as part of the Plan-Do-Study-Act (PDSA) cycle of continuous QI outlined by the United States Institute for Healthcare Improvement (IHI; Boston, Massachusetts USA).[5]

A recent study of characteristics of OHCA in the community of the Korean city of Ansan identified early cardiopulmonary resuscitation (CPR) as a weak link in the chain of survival.[6] The bystander CPR rate in that study was 13%, well below average rates of bystander CPR in the United States (40%) and Europe (47%).[7,8] This was felt to be due, at least in part, to the lack of resources previously invested in layperson CPR training.[9–11]

Additional concerns included emergency medical technician (EMT) CPR performance and documentation of bystander CPR, with no documentation regarding bystander CPR in 84% of cases. Implementing the PDSA model, study investigators developed a multi-faceted intervention intended to increase early CPR with the goal of improving survival from OHCA in the community of Ansan, which included: (1) developing a funded community education program to increase rates of bystander CPR; (2) initiating a QI program for EMT CPR performance within the Ansan Fire Department; and (3) establishing a data collection system for reliable capture of prehospital data with accurate measurement being a prerequisite for QI.[5] After implementation (the "Do" part of the cycle), the effect ("Study") was analyzed and the results used to identify the next target for intervention ("Act").

The purpose of this study was to illustrate the use of the PDSA model in informing a targeted community intervention to improve regional outcomes after OHCA and in identifying the next steps in the continuous cycle of QI.

Methods

Study Design

This study was a retrospective, observational cohort study using a standardized study data collection form and structured review of hospital medical records. This study was a subset of a larger project to improve the overall emergency medical response in the community of Ansan, overseen by the "Committee for Development in Emergency Medical Response in Ansan City." Participating committee members included directors and staff of the city's Public Health Center, the Fire Department, Emergency Medical Centers, civil society organization, and other municipal agencies. The study was approved by the institutional review board of Korea University Ansan Hospital (Ansan, Korea) and written informed consents were waived.

Population and Setting

Ansan city occupies 150 km^2 in the southwest of Gyeonggi-do province, near the metropolitan cities of Seoul and Incheon, with a population of just over 760,000, making it the fifth largest city in Gyeonggi province (Figure 1). It consists of residential and commercial areas, but it also has large industrial complexes and agricultural regions. Ansan EMS is provided by the Ansan Fire Department, which is the sole EMS provider for primary field response with basic and intermediate emergency medical technician (EMT) service levels distributed at 10 ambulance stations throughout the city. Emergency dispatchers are trained to identify possible OHCA. Dispatch protocols include telephone-assisted CPR and dispatch of intermediate-level EMTs to the scene. The EMTs arriving at the scene evaluate the patient and perform the resuscitation according to treatment protocols, and they are able to contact a physician for online medical control. If return of spontaneous circulation (ROSC) is not achieved after five cycles of CPR on-scene, the EMTs transport the patient to the nearest hospital with continued resuscitation en route. All EMTs can perform CPR and defibrillation at the scene and during transport. Advanced airway management and intravenous access are only performed by intermediate-level EMTs according to their treatment protocols. The EMS transport patients to the closest of 14 hospitals (12 hospitals in Ansan city and two hospitals in nearby cities) in the region. There are three hospital levels in Korea according to the mandated staffing, facility capabilities, and responsibilities: Level 1 hospitals are tertiary care centers who can manage critically ill patients 24/7; Level 2 hospitals are staffed with emergency physicians 24/7, but have less specialty services than Level 1 hospitals; and Level 3 hospitals only have a general physician on-duty with limited clinical departments or full-time services. Finally, hospitals without an emergency department (ED; designated as non-EDs) may receive EMS patients at a 24/7 clinic. Ansan city has two Level 2 hospitals certified by the government, of which one is a university teaching hospital. Additionally, the surrounding region has 12 hospitals, one of which is Level 2 located in a nearby city, and 11 that are Level 3 or non-EDs.

Description of Intervention

In 2012, a multifaceted intervention was implemented with the goal of improving early CPR in the community of Ansan. First, utilizing increased funding appropriated by Ansan city officials for bystander CPR education, "train the trainer" instruction was provided to EMS dispatchers who are responsible for instructing bystanders in CPR, and hands-only CPR training sessions were conducted for laypersons. The Korean Society of EMS Physicians (KSEMSP) performed lectures for dispatchers and instituted regular review of dispatch records. The dispatchers then conducted the CPR trainings for first responders, such as police officials, as well as laypersons. More than 3,000 persons were trained annually with the main targets being security guards; employees working in markets, hotels, or sports facilities; and teachers. Second, the medical director and emergency physicians at Korea University Ansan Hospital instituted regular skills training sessions for EMTs in that service area. Third, a detailed data collection instrument to be completed by EMTs for each cardiac arrest case was implemented, in addition to filling out a

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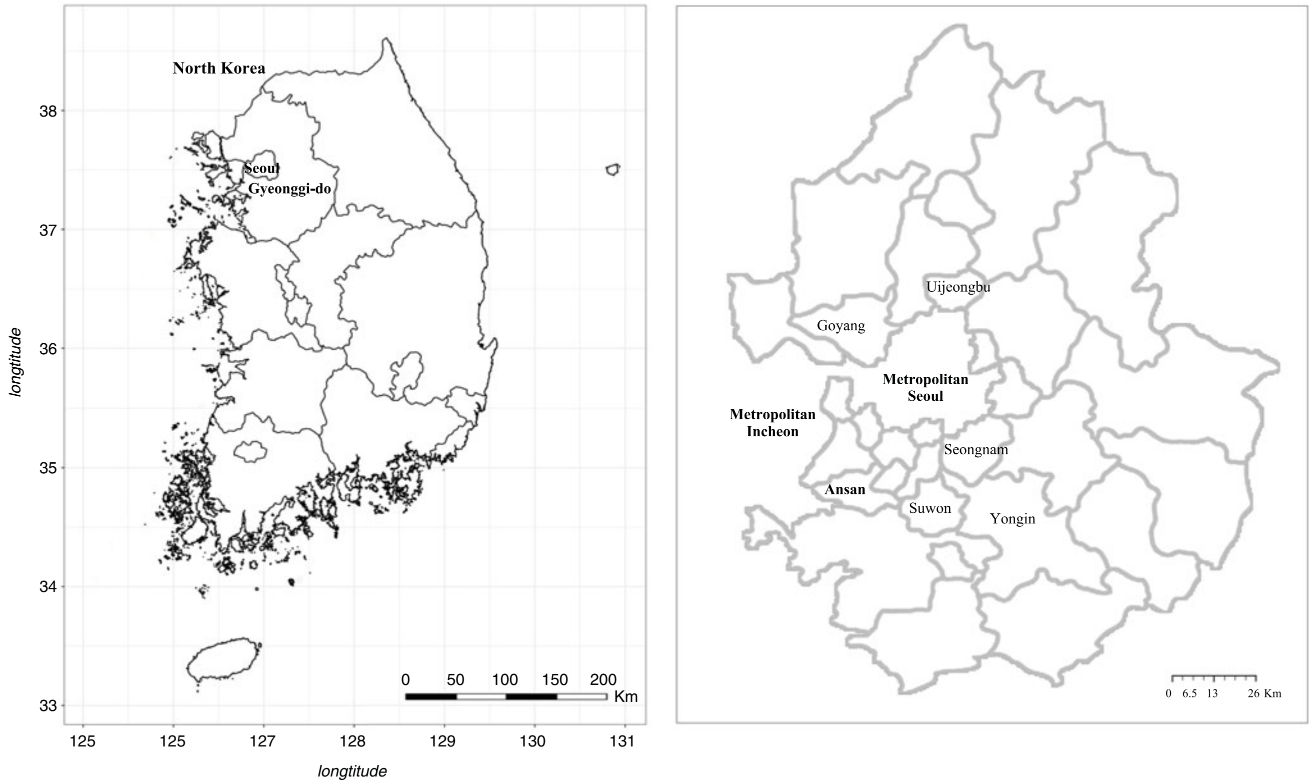

Figure 1. Map of Major Cities in Gyeonggi-do Province and Metropolitan Seoul and Incheon.

routine logbook. Finally, the Ansan Fire Department appointed an emergency physician for medical oversight of EMTs. This physician reviewed EMT documentation and provided feedback on both the documentation and the quality of care provided.

Selection of Participants

A list of EMS-assessed OHCA cases was obtained from the Ansan Fire Department. Study investigators identified all responses by the Ansan Fire Department for patients with OHCA from January 2008 through December 2013. The study cohort included adult patients 18 years or older with OHCA of presumed cardiac etiology assessed by EMS providers of the Ansan Fire Department from January 2008 through December 2011 (pre-intervention period) and from January 2012 through December 2013 (post-intervention period). Patients with non-cardiac etiology and those without available outcome data were excluded.

Measurements

From the EMS run sheets and OHCA data collection sheets completed by the EMTs, study investigators obtained information on patient age, gender, place of arrest, witness to arrest, performance of bystander CPR, whether pre-arrival instructions were given to the bystander, EMS response time interval (call to scene arrival), scene time interval (scene arrival to scene departure), EMS transport interval (scene departure to hospital arrival), initial rhythm documented by EMS providers, prehospital defibrillations, and receiving hospital. Probabilistic linkage was used to match the hospital medical record with the prehospital data utilizing the following characteristics: primary diagnosis of cardiac arrest, time of admission, patient age, and gender. Hospital data were abstracted from the medical records at each hospital by a trained nurse using a standard review sheet. From the hospital data, the investigators collected hospital interventions related to post-resuscitation care, including targeted temperature management (TTM), coronary angiography, and percutaneous coronary intervention (PCI), as well as patient outcome data including survival to hospital discharge and cerebral performance category score at hospital discharge or at transfer. Prehospital and hospital data definitions were based on the Utstein style reporting template.[12]

Analytical Methods

Data were entered into a Microsoft Excel file (Microsoft Corporation; Redmond, Washington USA) and transferred to R 3.4.3 (R Foundation for Statistical Computing; Vienna, Austria) for analysis. Frequencies and proportions or medians with interquartile range (IQR) were used to describe the two groups. Differences between demographic variables in the pre- and post-intervention periods were analyzed with students t-test for continuous normally distributed variables, Chi-square test for categorical variables, and Wilcoxon rank sum test for non-normally distributed continuous variables such as age. Adjusted odds ratios (AOR) and 95% confidence intervals (95% CI) for the effect of the intervention on ROSC and survival to hospital discharge were calculated using a generalized estimating equation with a logit link function and clustering by medical center, adjusting for potential confounders: age (divided into quartiles), gender, initial rhythm (shockable versus non-shockable), whether arrest was witnessed by layperson or EMS, bystander CPR, and receiving hospital level (dichotomized to Level 2 versus Level 3 or non-ED). Bystander CPR was not included as an independent variable because it was the target of the intervention and, therefore, risked to be collinear with the time period variable.

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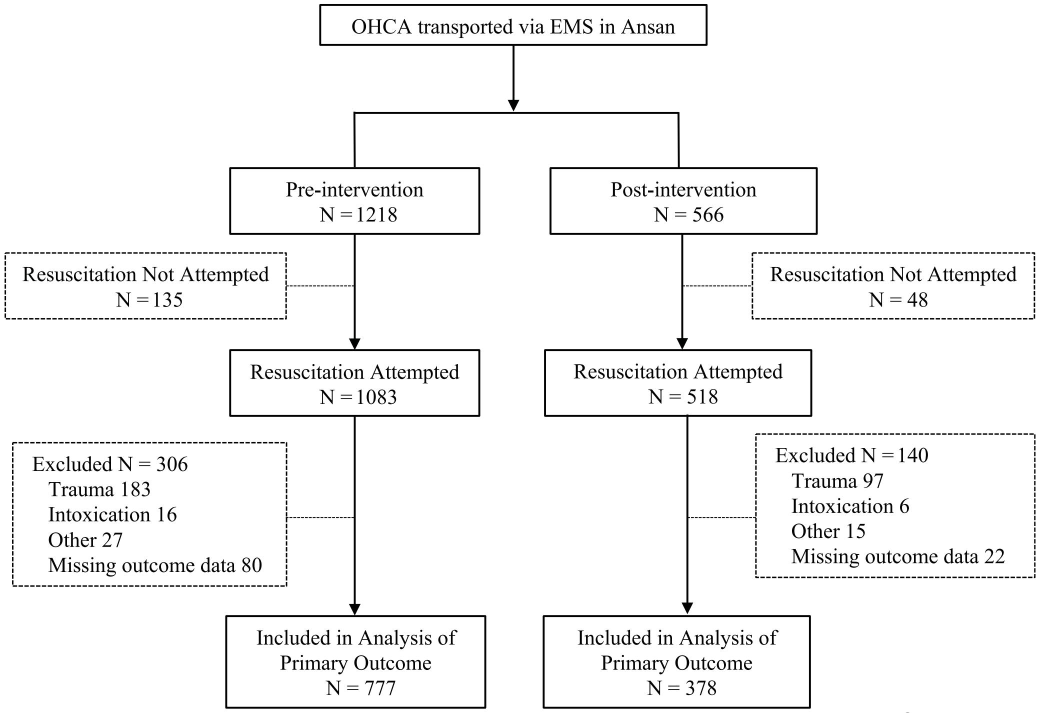

Figure 2. Schematic Flow of Selection Process for Enrolled Population.
Abbreviations: EMS, Emergency Medical Services; OHCA, out-of-hospital cardiac arrest.

Results

A total of 1,784 OHCA cases were assessed by EMS during the study period, 1,218 in the pre-intervention period and 566 in the post-intervention period. After exclusions, 1,155 patients were included in the analysis, 777 from the pre-intervention period and 378 from the post-intervention period (Figure 2). The demographic characteristics of the patients, as well as other descriptive variables related to the circumstances of the cardiac arrest pre- and post-intervention, are presented in Table 1 and Figure 3. With the exception of slightly longer response and scene times in the post-intervention period, the groups were similar.

Bystander CPR was performed in 37.4% of patients in the post-intervention period, excluding 20 cases which were EMS-witnessed, as compared to 13.2% in the pre-intervention period (risk difference [RD] 24.2%; 95% CI, 18.2%–29.4%). The overall rate of ROSC decreased from 18.4% to 14.3% (RD −4.1%; 95% CI, −7.1%–1.0%) between the pre-intervention period and post-intervention period, whereas survival to hospital discharge increased from 3.9% to 5.0% (RD 1.1%; 95% CI, −1.8%–3.8%), and survival with good neurologic outcome increased from 0.8% to 1.6% (RD 0.8%; 95% CI, −0.8%–2.4%).

In a multivariable logistic regression model, the post-intervention period was not significantly associated with increased odds of ROSC (OR 0.88; 95% CI, 0.68–1.16; Table 2). Factors associated with increased odds of ROSC included an initial shockable rhythm (OR 1.76; 95% CI, 1.30–2.39) and bystander-witnessed arrest (OR 3.04; 95% CI, 1.74–5.32). Factors that decreased the odds of ROSC were age greater than or equal to 70 years for ages 70–79 (OR 0.54; 95% CI, 0.32–0.90) and for age ≥80 (OR 0.42; 95% CI, 0.23–0.75), and transport to either a Level 3 or non-ED hospital (OR 0.62; 95% CI, 0.50–0.76).

Similarly, the post-intervention period was not significantly associated with increased odds of survival to hospital discharge (OR 1.37; 95% CI, 0.73–2.57; Table 3). Factors associated with increased odds of survival to hospital discharge included initial shockable rhythm (OR 4.13; 95% CI, 2.55–6.69) and EMS-witnessed arrest (OR 89.21; 95% CI, 4.70–1695). Factors associated with decreased odds of survival included age greater than or equal to 50 years for ages 50–69 (OR 0.66; 95% CI, 0.45–0.96), for ages 60–79 (OR 0.24; 95% CI, 0.12–0.48), and for ages ≥80 (OR 0.08; 95% CI, 0.04–0.17); as well as transport to either a Level 3 or non-ED hospital (OR 0.51; 95% CI, 0.31–0.81).

In the post-intervention period, 17 of the 19 patients who survived to hospital discharge were treated at two of the 14 receiving hospitals (Table 4), both of which were Level 2 hospitals with capabilities to perform coronary angiography and PCI. One of the two also performed TTM for patients after OHCA. No other hospitals performed PCI or TTM.

Discussion

The prior report investigating OHCA in Ansan from 2008 to 2011 found the overall survival rate to be 4.0% and the overall rate of good neurologic recovery to 0.8%.[6] After implementing an initiative to improve weak links in the chain of survival identified in the initial study – including low rates of bystander CPR and deficits in post-arrest care – the rate of survival to discharge increased to 5.0%, and the rate of good neurologic recovery among survivors increased to 1.6%. However, there was no significant association between the post-intervention period and the odds of survival, after adjusting for other confounders in the multivariable analysis. While overall rate of ROSC decreased from 18.4% to 14.3%, after adjusting for confounders, there was no significant association between the post-intervention period and odds of ROSC.

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Characteristics		Pre (N = 777) N (%)	Post (N = 378) N (%)	P
Gender	Male	458 (58.8)	238 (63.0)	.20
Age (Median, IQR)		69 (50–80)	69 (54–80)	.25
Location	Public	102 (13.0)	71 (18.8)	.20
	Home	510 (65.8)	249 (65.9)	
	Non-Public	165 (21.2)	58 (15.3)	
Witnessed By	EMS[c]	Unknown	20 (5.3)	NA
	Bystander	295 (37.9)	107 (28.3)	
	Unwitnessed	25 (3.2)	150 (39.7)	
	Unknown	457 (58.8)	101 (26.7)	
Bystander CPR[a]	Yes	103 (13.2)	140 (37.4)	NA
	No	21 (2.7)	188 (52.5)	
	EMS	Unknown	20 (5.3)	
	Unknown	653 (84.0)	30 (8.4)	
EMS Time (min) (Median, IQR)	Call to Scene Interval	6 (5–9)	8 (6–9)	<.01
	Scene Resuscitation Interval	5 (3–8)	8 (5–10)	<.01
	Scene to Hospital Interval	5 (3–7)	5 (3–6)	.81
Initial Rhythm	Shockable	85 (10.9)	46 (12.2)	1
	PEA	316 (40.7)	24 (6.3)	
	Asystole	115 (14.8)	229 (60.6)	
	Unknown	261 (33.5)	79 (20.9)	
Prehospital ROSC	Yes	9 (1.2)	7 (1.9)	1
	No	768 (98.8)	355 (93.9)	
	Unknown	0 (0)	16 (4.2)	
ED Level	Level 1 or 2	338 (43.5)	162 (42.9)	.20
	Level 3	162 (20.8)	71 (18.8)	
	Non-ED Facility	277 (35.7)	145 (38.4)	
Outcome[b]	Survival to Discharge	31 (4.0)	19 (5.0)	.21
	CPC 1–2	6 (0.8)	6 (1.6)	
	CPC 3–5	761 (99.2)	372 (98.4)	

Table 1. Characteristics of the Study Cohort
Abbreviations: CPC, cerebral performance category; CPR, cardiopulmonary resuscitation; ED, emergency department; EMS, Emergency Medical Services; PEA, pulseless electrical activity; ROSC, return of spontaneous circulation.

[a] Information to distinguish whether CPR at the scene of the arrest was performed by EMS or laypersons was not recorded during the 2008–2011 period.

[b] CPC outcomes for 10 surviving patients are unknown for the pre-intervention dataset.

[c] Information to distinguish whether an arrest was witnessed by EMS or bystanders was not recorded during the 2008–2011.

These findings are in contrast to several studies demonstrating improved survival with good neurologic outcome after OHCA with increased bystander interventions.[13,14] A similar study to this one, conducted in Seoul, Korea, found that an increase in the rate of bystander CPR from 5.3% to 12.4% was associated with an increase OR for survival of 1.33 (95% CI, 1.07 to 1.66).[15]

This suggests that there are other links in the chain of survival for OHCA in Ansan that mitigated the potential effect of bystander CPR on patient-centered outcomes. In particular, a significant association was noted between the receiving hospital designation level and the odds of both ROSC and survival to discharge. In this cohort, 57.2% of OHCA patients in Ansan were treated at the hospitals managed by non-emergency physicians (general physicians). These hospitals were not designated as EDs by the government, and only minimal cardiac arrest care was possible. The ROSC and survival rate from OHCA in patients treated at these hospitals were extremely low. Some districts in Ansan have no designated EDs, and these non-ED facilities are the only medical centers available to receive OHCA patients.

Other studies have also found inter-hospital variability in outcomes from OHCA.[16,17] Carr, et al found hospital volume was significantly associated with outcome, driven by poor outcomes at small hospitals.[16] Studies from North America suggest that survival is better when the OHCA patients are transferred to a specialized cardiac care center providing coronary reperfusion therapy and TTM.[18,19]

A study conducted in London (UK) reported that systematic transfer of cardiac etiology OHCAs to dedicated "heart attack centers" was associated with improved functional status and survival.[20] Aggressive in-hospital post-resuscitation care, including PCI and TTM, improve outcome, and transport to regional centers increases compliance with post-resuscitation care recommendations.[19,21,22]

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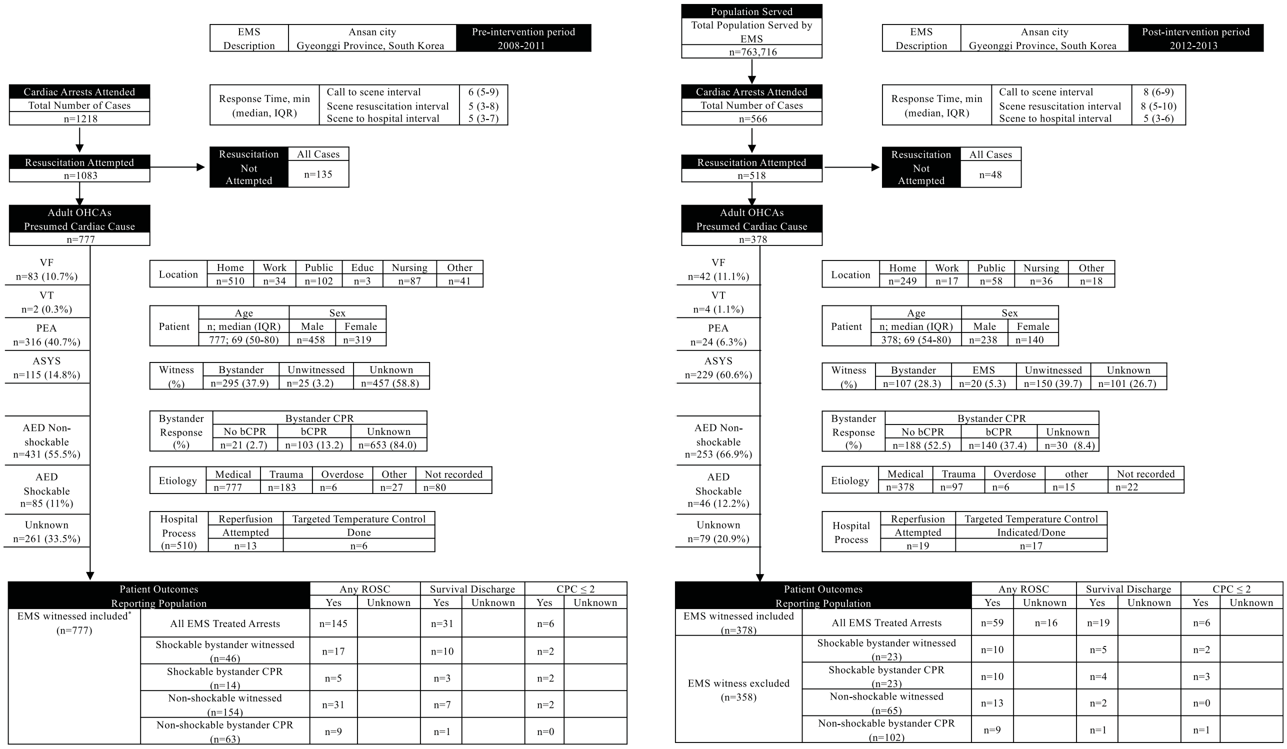

Figure 3. The Core Data Elements Based on Utstein Template for OHCA.
Abbreviations: AED, automated external defibrillator; ASYS, asystole; CPC, cerebral performance category; CPR, cardiopulmonary resuscitation; EMS, Emergency Medical Services; OHCA, out-of-hospital cardiac arrest; PEA, pulseless electrical activity; ROSC, return of spontaneous circulation; VF, ventricular fibrillation; VT, ventricular tachycardia.

Given that majority of patients with ROSC in most systems will not survive to hospital discharge, improving this link in the chain of survival can have a major impact on patient-centered outcomes. Poor in-hospital management can render improvements in out-of-hospital care ineffective. Therefore, based on these results, to improve survival and neurologic outcome of OHCA, Ansan must also focus on improving in-hospital care to reduce disparities between treating hospitals. Alternatively, or in addition, one could consider a protocol to bypass non-ED facilities in favor of higher-level facilities during the initial transportation of the patient from the field or inter-facility transfer of ROSC patients from non-ED facility to designated EDs. To maximize the effectiveness of the protocol, establishing core requirements for cardiac arrest-receiving hospitals and monitoring quality of post-arrest care is also necessary. Although the rate of PCI performed in ROSC patients increased from 2.6% pre-intervention to 5.0% post-intervention, and the rate of TTM increased from 1.2% to 9.5%, these are still relatively low rates and only one hospital implemented both therapies.[6]

A final element that needs to be considered is the low rates of out-of-hospital ROSC given the short scene time, which is driven, at least in part, by a protocol to administer only five rounds of CPR prior to transport. The average scene times were only five and eight minutes in the pre- and post-intervention period, respectively. The Korean national emergency care protocol for EMS providers recommends a minimum of five minutes on-scene,[23] which differs from most systems in the United States. This may reflect a difference in EMT scope of practice, since EMTs in Ansan do not administer vasopressors or antidysrhythmic agents during OHCA resuscitation. However, neither epinephrine nor amiodarone, routinely used by paramedics in the US, have been shown to improve survival with good neurologic outcome from OHCA.[24,25] Further, in a cohort of OHCA patients treated in Seoul and Osaka, Shin, et al demonstrated that a longer scene time of eight to 16 minutes was associated with improved survival with good neurologic outcome.[26] Therefore, increasing the on-scene resuscitation time, particularly in conjunction with establishing cardiac receiving centers with local facility bypass, should be considered.

This study is an example of implementation of the PDSA model for QI in the EMS system in Ansan. While the initial intervention to improve bystander CPR and quality prehospital resuscitation did not result in improved patient-centered outcomes, evaluation of the post-intervention data revealed the next targets for improvement, including the timing of on-scene resuscitation and the quality of in-hospital post-resuscitation care.

Limitations

There are several limitations in this study. Given the observational retrospective nature of the study, one cannot determine causality despite finding associations between treating hospital level and outcomes. Although the data were reviewed in accordance with the Utstein template, the review was retrospective, and it is possible that there were inaccuracies or omissions in these records. Starting in 2012, Ansan EMS started to prospectively collect data on OHCA resuscitations. However, the prehospital data for the pre-intervention period were extracted from the hospital medical review, resulting in a large proportion of missing data. In particular, the majority of resuscitations were missing documentation regarding

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		Adjusted OR	95% CI
Time Period	Pre-Intervention	Reference	
	Post-Intervention	0.88	0.68–1.16
Gender	Female	Reference	
	Male	1.23	0.95–1.60
Age (years)	First Quartile (18–49)	Reference	
	Second Quartile (50–69)	0.87	0.58–1.31
	Third Quartile (70–79)	0.54	0.32–0.90
	Fourth Quartile (≥80)	0.42	0.23–0.75
Witnessed	Unwitnessed	Reference	
	EMS	2.03	0.48–8.67
	Bystander	3.04	1.74–5.32
	Unknown	1.62	0.90–2.92
Initial Rhythm	Non-Shockable	Reference	
	Shockable	1.76	1.30–2.39
	Unknown	1.12	0.90–1.39
Hospital Level	Level 2	Reference	
	Level 3 or Non-ED	0.62	0.50–0.76

Table 2. Multivariable Logistic Regression Model of Association of Intervention on Return of Spontaneous Circulation (N = 1,155)
Abbreviations: ED, emergency department; EMS, Emergency Medical Services.

		Adjusted OR	95% CI
Time Period	Pre-Intervention	Reference	
	Post-Intervention	1.37	0.73–2.57
Gender	Female	Reference	
	Male	1.49	0.70–3.21
Age (years)	First Quartile (18–49)	Reference	
	Second Quartile (50–69)	0.66	0.45–0.96
	Third Quartile (70–79)	0.24	0.12–0.48
	Fourth Quartile (≥80)	0.08	0.04–0.17
Witnessed	Unwitnessed	Reference	
	EMS	89.21	4.70–1695.17
	Bystander	14.89	0.95–233.96
	Unknown	6.73	0.45–101.25
Initial Rhythm	Non-Shockable	Reference	
	Shockable	4.13	2.55–6.69
	Unknown	1.03	0.43–2.44
Hospital Level	Level 1 or 2	Reference	
	Level 3 or Non-ED	0.51	0.31–0.81

Table 3. Multivariable Logistic Regression Model of Association of Intervention on Survival to Hospital Discharge (N = 1,155)
Abbreviations: ED, emergency department; EMS, Emergency Medical Services.

performance of bystander CPR. Improved documentation was also a target of the intervention. Therefore, the effect of the intervention on increased performance of bystander CPR cannot be separated from the improvement that may have occurred in the documentation alone. Further, in the pre-intervention period, data on whether EMS witnessed the arrest were not collected, so these cases could not be excluded from the patient outcomes according to the usual Utstein reporting populations. There were statistically significant differences in scene times between the pre-intervention and post-intervention period. Given these times were hand-recorded by EMTs rather than electronically captured, the differences more likely represent changes in the quality of documentation that occurred after the program for medical director oversight of EMTs was established. An a priori power calculation was not performed. Although the results did not show a significant effect of the intervention on the rates of ROSC and cardiac arrest survival, the

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Treating Hospital	Level	Total OHCA	PCI N (%)	TTM N (%)	SHD N (%)
A	Non-ED	8	0 (0)	0 (0)	0 (0)
B[a,b]	2	76	7 (9.2)	17 (22.4)	10 (13.2)
C	Non-ED	5	0 (0)	0 (0)	0 (0)
D[a]	2	84	12 (14.3)	0 (0)	7 (8.3)
E	Non-ED	37	0 (0)	0 (0)	0 (0)
F	Non-ED	29	0 (0)	0 (0)	0 (0)
G	3	19	0 (0)	0 (0)	0 (0)
H	Non-ED	85	0 (0)	0 (0)	1 (1.2)
I	3	4	0 (0)	0 (0)	0 (0)
J	3	11	0 (0)	0 (0)	0 (0)
K	3	8	0 (0)	0 (0)	0 (0)
L	2	1	0 (0)	0 (0)	1 (100)
M	Non-ED	1	0 (0)	0 (0)	0 (0)
N	Non-ED	10	0 (0)	0 (0)	0 (0)
Total		378	19 (5.0)	17 (9.5)	19 (5.0)

Table 4. Survival to Discharge by Hospital in Ansan in the Post-Intervention Period
Abbreviations: ED, emergency department; OHCA, out-of-hospital cardiac arrest; PCI, percutaneous coronary intervention; SHD, survival to hospital discharge; TTM, targeted temperature management.
[a] Performed percutaneous coronary angiography.
[b] Performed therapeutic hypothermia.

study may have been unpowered to detect a clinically significant difference. Finally, the study was conducted in a single region in Korea and may not be directly generalizable to other systems. However, this process provides an example of an approach to QI that can be used by many EMS systems.

Conclusion

In this case study, there were no observed improvements in outcomes from OHCA after the targeted intervention to improve out-of-hospital CPR. However, utilizing the PDSA model for QI, the designated level of the treating hospital was found to be a significant predictor of survival in the post-period, identifying the next target for intervention.

Author Contributions

HJC and SWM conceived of and implemented the study. JHP and JHS supervised each study site. HL and HJY abstracted the prehospital and hospital data. HJC and JT performed the statistical analysis. NB and RL provided guidance on data interpretation and contextual focus. JYK, JT, and NB each drafted sections of the manuscript, and all others contributed substantially to its revision.

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