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ORIGINAL RESEARCH

Association between prehospital airway management methods and neurologic outcome in out-of-hospital cardiac arrest with respiratory cause: a nationwide retrospective observational study

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Abstract

Cardiac arrests are resulted by various aetiology including respiratory cause. Advanced airway placement is an important prehospital intervention for oxygenation and ventilation in respiratory cardiac arrest. We evaluated the association between of advanced airway method and neurologic outcome in arrest with respiratory cause. Adult witnessed non-traumatic OHCA (out-of-hospital cardiac arrest) treated by emergency medical service (EMS) providers in 2013–2017 were enrolled in a nationwide OHCA database. The association between airway management methods (endotracheal intubation (ETI), supraglottic airway (SGA) and bag valve mask (BVM)) and outcome were evaluated according to the presumed cause of cardiac arrest (cardiac, respiratory or others). The primary outcome was good neurological recovery at discharge. Multivariable logistic regression models with interaction analysis was conducted. Of 40,443 eligible OHCA patients, the cause of arrest of 90.0%, 7.5%, and 2.4% of patients were categorized as cardiac, respiratory and others, respectively. There were no statistically significant differences in the effect of the advanced airway type on good neurologic recovery in the total population (adjusted odds ratio (aOR) 0.96 (0.81–1.14) for ETI; 1.01 (95% confidence intervals (CI) 0.93–1.11) for BVM). However, ETI was associated with better neurologic recovery than SGA or BVM in OHCA in cardiac arrest with suspected respiratory cause (aOR 3.12 (95% CI 1.24–7.80) for ETI; 0.99 (95% CI 0.51–1.91) for BVM). Prehospital ETI was associated with good neurologic outcome when the cause of arrest was respiratory. ETI may be considered initially when a respiratory cause is suspected on the scene.

Keywords

Out-of-hospital cardiac arrest; Emergency medical service; Advanced airway placement; Respiratory cause

1. Introduction

Various etiologies are responsible for the occurrence of out-of-hospital cardiac arrest (OHCA) [1, 2]. Although majority of OHCA is caused by cardiac cause, respiratory problems resulting from hypoxia and hypoventilation in conditions such as ARDS, pneumonia, COPD and asphyxia also cause cardiac arrest [3–5]. For cardiac arrest caused by respiratory aetiology, resuming and providing oxygenation and ventilation during cardiac arrest is especially important for correcting the cause of arrest and minimizing neurological damage in the brain [6, 7].

Advanced airway placement is one of the key prehospital interventions performed by emergency medical service (EMS) providers during field resuscitation of OHCA [8]. The main purpose of advanced airway placement is to provide more effective oxygenation and ventilation than basic airway such as bag-valve-mask (BVM) [9, 10]. Various studies have compared the effects of prehospital advanced airway management methods on outcomes in OHCA, but they are mostly tested in cardiac arrest with presumed cardiac cause the results are still controversial [11–15].

However, little is known about the association of prehospital advanced airway management and outcome according to the cause of cardiac arrest.

In this study, we investigated the association between prehospital advanced airway method and neurologic outcome according to the presumed cause of cardiac arrest under the hypothesis that the effect of each advanced airway management type would be different when cause of arrest is suspected to be respiratory.

2. Methods

2.1 Study design and setting

A retrospective observational study was conducted using the prospectively collected nationwide EMS based OHCA registry of Korea. In Korea, a single national fire agency exclusively operates the prehospital EMS system. In cases of OHCA, EMS providers perform basic life support (BLS), including the use of automatic defibrillators for rhythm analysis and defibrillation. EMS providers have no authority to declare death or stop cardiopulmonary resuscitation (CPR) unless there is return of spontaneous circulation (ROSC). Prehospital EMS providers in Korea are mostly emergency medical technicians (EMTs) and nurses. The majority of EMS providers are EMTs, for whom there are two levels of national certification (Level-1 EMT and Level-2 EMT). Level-1 EMTs provide services similar to EMT-intermediate services in EMS systems in United States. Advanced airway placement can only be performed by a Level-1 EMT or a nurse under direct medical control from a medical director on the phone. Endotracheal intubation or supraglottic airway insertion, such as I-gel and laryngeal mask airway (LMA), are also available. The decision to perform advanced airway placement and selection between airway techniques is usually at the discretion of an on-duty EMS provider.

2.2 Data source

The Nationwide OHCA database, which includes all EMS-assessed OHCAs, was retrieved from the following four sources: the EMS run sheets for basic ambulance operation information, the EMS cardiac arrest registry, the dispatcher CPR registry for the Utstein factors, and the hospital medical record review registry for hospital care and outcomes. A detailed description of the data acquisition of each registry, as well as the training and quality of the medical record reviewers, have been described in previous studies [16, 17].

2.3 Study population

All adult witnessed OHCAs assessed and treated by EMS providers from January 2013 to December 2017 were initially enrolled. OHCAs witnessed by EMTs during transport (whose selecting airway management method could different from bystander witnessed OHCA patients), OHCAs treated only by EMS teams consisting of level 2 EMTs only (who could not perform advanced airway placement) and OHCAs with unknown survival and neurologic outcome were excluded. We also excluded OHCAs with traumatic cause.

2.4 Exposure and outcome variables

The primary exposure of interest was the type of airway management method. The leader of the EMS team at the scene recorded a detailed OHCA registry, including the method of airway management. The leader of the team recorded whether the advanced airway was attempted, if it was successful (and if successful, the time of advanced airway placement) and the type of advanced airway method attempted (endotracheal intubation or supraglottic airway (Combitube, LMA, King airway or I-gel)). Current guidelines for prehospital EMS management recommend that level-1 EMTs or nurses can perform advanced airway placement according to their preference under direct medical direction. The guidelines recommend the procedure should take less than 30 seconds and that attempts should be performed up to 2 times. The primary outcome of the study was good neurological recovery at hospital discharge, defined as a cerebral performance category (CPC) 1 or 2. Medical record reviewers assessed the CPC score based on discharge summary abstracts or documented medical records. Secondary outcome was survival to hospital discharge.

2.5 Cause of cardiac arrest

Pathogenesis of cardiac arrest in the database is determined by trained medical record reviewers after reviewing hospital records of patients according to Ustein recommendation [18]. In our analysis, we recategorized the cause of arrest into three groups after excluding traumatic arrest. Cause of arrest was presumed to be cardiac unless there was evidence to suggest a non-cardiac cause. Cardiac arrests caused by obvious aggravation of respiratory disease, asphyxia (including foreign body airway obstruction), drowning (submersion) or hanging were categorized as respiratory group. Lastly, remaining arrests by other etiologies such as poisoning or electrocution were categorized as others. We excluded traumatic arrest other than asphyxia, drowning and hanging from our study.

2.6 Statistical analysis

Demographics, EMS management, hospital management and outcomes were compared by cause of arrest using the χ^2 test for categorical variables and one-way analysis of variance (ANOVA) or the Kruskal-Wallis test for continuous variables.

Multivariable logistic regression was conducted to analyze the effect of airway management method on the outcome and is presented as the odds ratios (ORs) with 95% confidence intervals (CI) after adjusting for covariables. The variables included in the model were age, gender, location of arrest, bystander CPR, response time interval, hypertension and heart disease. We tested for multicollinearity between the covariables in the model, and there was no multicollinearity. Hosmer and Lemeshow goodness of fit test was done to check goodness of fit for logistic regression models. And concordance statistic (C-statistics, area under a receiver operating characteristic curve) was calculated. To assess changes in the effect of airway management according to the cause of arrest, we added an interaction analysis between airway management methods and the cause. STATA 14.1 (StataCorp, College Station, TX, USA) was used for all analyses.

3. Results

In total, 145,003 OHCA patients in our registry were initially enrolled from January 2013 to December 2017. Patients aged less than 18 years (N = 3170), patients with OHCA not witnessed (N = 79,208), patients not treated by EMS providers (N = 4063), patients with cardiac arrests occurring during ambulance transport (N = 7203), patients treated by EMS teams without any level-1 EMTs capable of advanced airway placement (N = 5756), traumatic cause (N = 5062) and patients with unknown outcome (prehospital ROSC, survival and neurologic outcome) (N = 98) and were excluded (Fig. 1).

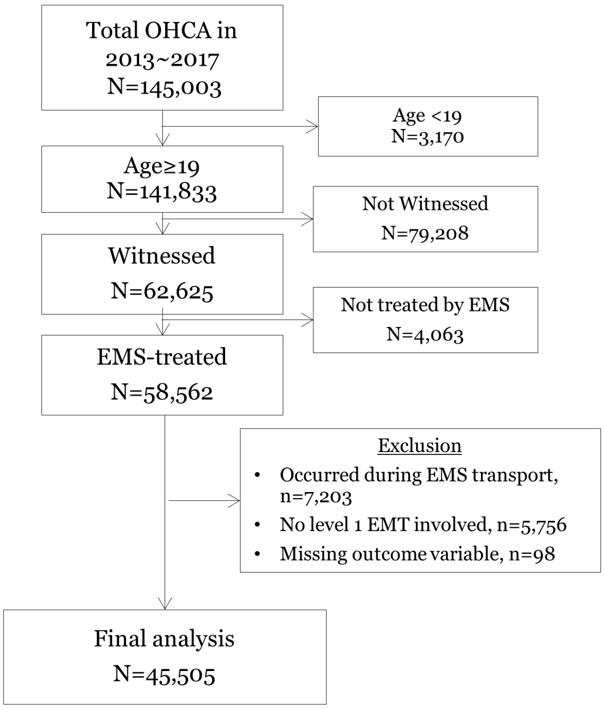

FIGURE 1. Enrollment flow of study population. OHCA, out-of-hospital cardiac arrest; EMS, emergency medical service; EMT, emergency medical technician.

After serial exclusion, 40,443 OHCA patients were included in the final analysis. Regarding the presumed cause of arrest, 36,404 (90.0%) cases were cardiac, 3050 (7.5%) were respiratory and 989 (2.4%) were others. The demographic characteristics according to cause are summarized in Table 1. The proportion of advanced airway placement differed according to the group, and the rate of endotracheal intubation was highest in the respiratory cause group (6.7% vs. 8.1% vs. 5.1%, respectively, $p < 0.01$). The neurologically favorable survival-to-discharge rates were 12.5% in the cardiac group, 9.6% in the respiratory group, and 12.1% in the others group (Table 1, $p <$ 0.01).

In the multivariable logistic regression analysis, there was no statistically significant association between type of airway management and good neurologic recovery (SGA as reference, aOR (95% CI) 1.01 (0.93–1.11) for BVM; 0.96 (0.81–1.14) for ETI) and survival to discharge (SGA as reference, aOR (95% CI) 0.96 (0.89–1.03) for BVM; 0.96 (0.83–1.11) for ETI) in the total population (Table 2). For multivariate model of good neurological outcome, *p*-value of Hosmer and Lemeshow goodness of fit test was less than 0.01 and C-statistics was 0.84. For multivariate model of survival to discharge, *p*-value of Hosmer and Lemeshow goodness of fit test was less than 0.01 and C-statistics was 0.78.

In the interaction analysis, the magnitude of the association between type of advanced airway and outcome measures was different according to the presumed cause of cardiac arrest. ETI was associated with significantly better neurological recovery than SGA (aOR 3.12 (95% CI 1.24–7.80)) and BVM (aOR 3.16 (95% CI 1.43–6.98)) when the cause of arrest was respiratory. Although the effect of ETI was nonsignificant, BVM was associated with lower survival to discharge than SGA when the cause of arrest was respiratory (aOR 0.70 (95% CI 0.52–0.94)) (Table 3). For interaction analysis model of good neurological outcome, *p*-value of Hosmer and Lemeshow goodness of fit test was less than 0.01 and C-statistics was 0.84. For interaction analysis model of survival to discharge, *p*-value of Hosmer and Lemeshow goodness of fit test was less than 0.01 and C-statistics was 0.78.

4. Discussion

In this analysis of a nationwide, population-based OHCA registry, we evaluated the association between prehospital advanced airway methods and clinical outcome of cardiac arrest. The magnitude of the association was different according to the presumed cause of cardiac arrest. There was no statistically significant difference in the effect according to the advanced airway type in total population and arrest with cardiac origin. However endotracheal intubation was associated with better neurologic outcome when the cause of arrest was respiratory. We believe more efficient oxygenation and ventilation through prehospital endotracheal intubation provides a rapid and effective solution to respiratory cause of cardiac arrest, as an antidote for drug intoxication. Although most of cardiac arrest cases receive endotracheal intubation eventually after hospital transport, faster reversal of hypoxia and hypoventilation by prehospital endotracheal intubation in the field might show an effect on minimizing hypoxic brain injury. Based on the results of our study, we suggest that endotracheal intubation might be considered as a first choice of method in OHCA patients whose cause of arrest is suspected to be respiratory, such as respiratory disease, asphyxia and strangulation.

Even after recent prospective clinical trials, defining the optimal choice of prehospital advanced airway methods in OHCA is controversial. Wang *et al.* [13] compared laryngeal tube and ETI as prehospital airway management methods for OHCA and showed that LT was superior to ETI when measuring 72-hour survival. Benger *et al.* [19] compared I-gel versus ETI, and there was no difference in survival to discharge or favorable neurologic outcome rate. Jabre *et al.* [12] compared BVM to ETI and obtained inconclusive results regarding 28-day survival with favorable neurologic outcome. Overall, the results showed no definite benefit of ETI over BVM or SGA. In a nationwide cohort study conducted in Japan, advanced airway management (ETI and SGA) was associated with better survival and more favorable neurologic outcomes compared with no advanced airway management in non-shockable (pulseless electrical activity and asystole) OHCA patients [20]. However, these studies did not consider the etiologies of arrest.

The supraglottic airway can be inserted blindly and therefore has a higher success rate than endotracheal intubation, even for those with low skills, such as EMS providers in Korea. However, compression of important structures such as carotid vessels has been suggested in animal studies in some SGAs due to its morphologic characteristics and mechanism [21, 22]. In

TABLE 1. Demographic and clinical characteristics according to etiology of arrest.

	Total		Cardiac		Respiratory		Miscellaneous		*p*-value
	N	%	N	%	N	%	N	%	
Total	40,443		36,404	90.0	3050	7.5	989	2.4	
Age (mean (SD), years)	68.5 (16.0)		68.9 (15.6)		66.9 (18.6)		59.2 (17.4)		<0.001
Male	25,925	64.1	23,334	64.1	1886	61.8	705	71.3	<0.001
Past medical history									
Heart disease	6555	16.2	6297	17.3	192	6.3	66	6.7	<0.001
Hypertension	13,290	32.9	12,361	34.0	754	24.7	175	17.7	<0.001
Diabetes mellitus	8427	20.8	7811	21.5	509	16.7	107	10.8	<0.001
Stroke	3673	9.1	3290	9.0	347	11.4	36	3.6	<0.001
Place of arrest									
Private place	31,090	76.9	28,223	77.5	2296	75.3	571	57.7	<0.001
Bystander CPR	25,331	62.6	22,818	62.7	1961	64.3	552	55.8	<0.001
Bystander AED	1375	3.4	1217	3.3	114	3.7	44	4.4	0.09
Initial rhythm									<0.001
VF/VT	9521	23.5	9179	25.2	145	4.8	197	19.9	
PEA	7400	18.3	6597	18.1	661	21.7	142	14.4	
Asystole	22,928	56.7	20,115	55.3	2176	71.3	637	64.4	
Unknown	594	1.5	513	1.4	68	2.2	13	1.3	
Prehospital airway management									<0.001
SGA	11,460	28.3	10,500	28.8	736	24.1	224	22.6	
BVM	26,244	64.9	23,462	64.4	2067	67.8	715	72.3	
ETI	2739	6.8	2442	6.7	247	8.1	50	5.1	
Prehospital epinephrine	3275	8.1	3049	8.4	174	5.7	52	5.3	<0.001
EMS time interval (median [IQR], min)									
Response time interval	7.0 [5.0, 10.0]		7.0 [5.0, 9.0]		7.0 [5.0, 10.0]		8.0 [5.0, 11.0]		<0.001
Scene time interval	11.0 [8.0, 15.0]		11.0 [8.0, 15.0]		10.5 [7.0, 15.0]		10.0 [6.0, 14.0]		<0.001
Post resuscitation care									
Reperfusion	2511	6.2	2476	6.8	15	0.5	20	2.0	<0.001
Hypothermia	1762	4.4	1505	4.1	195	6.4	62	6.3	<0.001
ECMO	505	1.2	483	1.3	13	0.4	9	0.9	<0.001
Survival outcome									
Prehospital ROSC	5678	14.0	5347	14.7	215	7.0	116	11.7	<0.001
Survival to discharge	4965	12.3	4551	12.5	294	9.6	120	12.1	<0.001
Good CPC	3188	7.9	3057	8.4	60	2.0	71	7.2	<0.001

SD, standard deviation; CPR, cardiopulmonary resuscitation; AED, automated external defibrillator; VT, ventricular tachycardia; VF, ventricular fibrillation; PEA, pulseless electrical activity; SGA, supraglottic airway; ETI, endotracheal intubation; BVM, bag valve mask; IQR, interquartile range; ECMO, extracorporeal membrane oxygenation; Good CPC, CPC 1 or 2.

severe hypoxia in respiratory arrest, carotid blood flow reduction caused by SGA insertion might be more critical than for other etiologies of cardiac arrest. One case reported ventilation failure of a drowned patient with supraglottic airways due to leakage from high pressure [23].

Several previous studies have reported negative effects of prehospital advanced airway placement on the outcome of respiratory cardiac arrest [15, 24]. However, these studies included only limited number of patients with medical intrinsic respiratory disease, excluding external causes of arrest, such as asphyxia or hanging. Additionally, the studies only tested the overall effect of prehospital advanced airway rather than the effect of each advanced airway method according to different etiologies, as in our study.

Only witnessed cardiac arrests were enrolled for analysis in our study. We opted not to include patients with arrest not witnessed by initial bystanders. Although our study was a retrospective observational study and there are currently no guidelines for EMS providers to consider cause of arrest when selecting the airway management method, we supposed

TABLE 2. Multivariable logistic regression analysis by type of prehospital airway management method.

	Total	Good neurological outcome					Survival to discharge				
	N	n (%)	Unadjusted		Adjusted		n (%)	Unadjusted		Adjusted	
			OR	95% CI	OR	95% CI		OR	95% CI	OR	95% CI
All	40,443	3188 (7.9)					4965 (12.3)				
SGA	11,460	974 (8.5)	1.00				1540 (13.4)	1.00			
BVM	26,244	2015 (7.7)	0.89	(0.73–0.97)	1.01	(0.93–1.11)	3090 (11.8)	0.86	(0.81–0.92)	0.96	(0.89–1.03)
ETI	2739	199 (7.3)	0.84	(0.72–0.99)	0.96	(0.81–1.14)	335 (12.2)	0.90	(0.79–1.02)	0.96	(0.83–1.11)

OR, odds ratio; CI, confidence interval; SGA, supraglottic airway; ETI, endotracheal intubation; BVM, bag valve mask.

TABLE 3. Multivariable logistic regression with interaction analysis between airway management methods and the etiology.

	Good neurological outcome			Survival to discharge		
	N (%)	aOR	95% CI	N (%)	aOR	95% CI
Cardiac						
SGA (n = 10,500)	942 (9.0)	1.00		1425 (13.6)	1.00	
BVM (n = 23,462)	1929 (8.2)	1.02	(0.93–1.11)	2827 (12.0)	0.96	(0.89–1.03)
ETI (n = 2442)	186 (7.6)	0.92	(0.77–1.10)	299 (12.2)	0.96	(0.83–1.11)
Respiratory						
SGA (n = 736)	13 (1.8)	1.00		84 (11.4)	1.00	
BVM (n = 2067)	38 (1.8)	0.99	(0.51–1.91)	181 (8.8)	0.70	(0.52–0.94)
ETI (n = 247)	9 (3.6)	3.12	(1.24–7.80)	29 (11.7)	1.35	(0.83–2.18)
Miscellaneous						
SGA (n = 224)	19 (8.5)	1.00		31 (13.8)	1.00	
BVM (n = 715)	48 (6.7)	0.98	(0.31–3.11)	82 (11.5)	1.53	(0.61–3.85)
ETI (n = 50)	4 (8.0)	1.15	(0.11–11.91)	7 (14.0)	1.59	(0.28–9.07)

aOR, adjusted odds ratio; CI, confidence interval; SGA, supraglottic airway; ETI, endotracheal intubation; BVM, bag valve mask.

it might be difficult for EMS providers to estimate the cause of arrest in unwitnessed cases. We believe that, for witnessed cardiac arrest, EMS providers can presume the cause of cardiac arrest based on a history taken from the bystander who witnessed the arrest or could at least determine whether the cause was respiratory or not. Based on the result of our study, we suggest that EMS providers might consider estimated cause when deciding the airway management method in the field.

A previous study reported negative association between prehospital advanced airway management and neurologic outcome of OHCA [15], we believe there are two different points between the study and our study. First, patient population of two studies was different because criteria used to define respiratory disease were different. Ohashi-Fukuda's study was conducted on a population with the etiology of cardiac arrest as respiratory disease such as pneumonia, tuberculosis, chronic obstructive pulmonary disease, or asthma. Respiratory group in our study was categorized as cardiac arrests caused by obvious aggravation of respiratory disease, asphyxia (including foreign body airway obstruction), drowning(submersion) or hanging. Second, exposure of study performed by Ohashi *et al.* [15, 24] was advanced airway management, which combined laryngeal mask airway, oesophageal obturator airway, endotracheal tube. although subgroup analysis on methods of each airway devices shows poor neurological outcome consistently, laryngeal mask airway (aOR 0.35 (0.19–0.57)), oesophageal obturator airway (aOR 0.44 (0.35–0.55)), endotracheal tube (aOR 0.47 (0.30–0.69)) shows different effect between methods of each advanced airways. Our study analyzed each advanced airway method separately.

There are some limitations to our study. First, this was a retrospective observational study; therefore, careful interpretation is needed considering the unique characteristics of our EMS system. Second, we extracted cause of arrest by medical record review. For patients who did not achieve any ROSC and were pronounced dead after initial resuscitation, there might be few clues to estimate the cause of arrest. Third, the number of patients with favorable neurological outcome in the ETI group with respiratory arrest were very small (9 patients), which leading to wide confidence intervals and making results difficult to interpret. Furthermore, detailed diagnosis of respiratory disease or severity of trauma were not included in our database. Last, there might be unmeasured confounders not included in our registry that could affect both airway management method and outcome.

Also, there were some strengths in our study. First, this was a relatively large-scale nationwide study. Second, with Korea's prehospital EMS system exclusively operated by national fire agency nationwide protocol was unified and EMS services were homogenous nationwide. Third, our study might suggest tailored therapy with prehospital stage information on treatment of OHCA.

Regarding the generalizability of our study, we can consider applying it to the Asian, scoop and run EMS model environment rather than the North American or European EMS model.

5. Conclusions

The association between prehospital advanced airway and the neurological outcomes of patients with witnessed non-traumatic OHCA was not significant. However, endotracheal intubation was associated with better neurologic recovery in cardiac arrest with respiratory cause. Endotracheal intubation may be considered initially by EMS providers when a respiratory cause is suspected for the pathogenesis of cardiac arrest.

AUTHOR CONTRIBUTIONS

YC and THK had full access to all of the data in the study and take responsibility for the integrity of the data as well as the accuracy of the data analysis. Study concept and design—YC, THK and SDS; acquisition, analysis, or interpretation of data—THK, KJH and KJS; drafting of the manuscript—YC; critical revision of the manuscript for important intellectual content—THK, KJS, and SDS; statistical analysis—THK and YC; administrative, technical, or material support—KJS and SDS; study supervision—SDS, KJS and THK; manuscript approval—all authors.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the Seoul National University Hospital Institutional Review Board with a waiver of informed consent (IRB No. 1103-153-357). The first approval date was June 8th, 2011.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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