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Clinical paper

Out-of-hospital airway management and cardiac arrest outcomes: A propensity score matched analysis☆

Sang Do Shin[a,*], Ki Ok Ahn[b], Kyoung Jun Song[a], Chang Bae Park[a], Eui Jung Lee[c]

[a] Department of Emergency Medicine, Seoul National University College of Medicine, Republic of Korea
[b] Department of Emergency Medicine, Kangwon National University College of Medicine, Republic of Korea
[c] Department of Emergency Medicine, Jeju National University College of Medicine, Republic of Korea

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ABSTRACT

Objective: It is unclear whether advanced airway management during ambulance transport is associated with improved out-of-hospital cardiac arrest (OHCA) outcomes compared with bag-valve mask ventilation (BVM). This study aimed to determine whether EMT-intermediate ETI or LMA is associated with improved OHCA outcomes in Korea.

Methods: We used a Korean national OHCA cohort database composed of hospital and ambulance data. We included all EMS-treated by level 1 EMTs (EMT-intermediate level) and OHCA with presumed cardiac etiology for the period January 2006–December 2008. We excluded cases not receiving continued resuscitation in the emergency department (ED), treated by level 2 EMT, as well as those without available hospital outcome data. The primary exposure was airway management technique during ambulance transport (endotracheal tube (ETI), laryngeal mask airway (LMA) or bag-valve-mask ventilation with an oropharyngeal airway). The primary outcomes were survival to admission and survival to hospital discharge. We compared outcomes between each airway management group using multivariable logistic regression, adjusting for sex, age, witnessed, prehospital defibrillation, bystander cardiopulmonary resuscitation (CPR), call to ambulance arrival time to the scene, call to ambulance arrival time to ED, initial ECG, metropolitan (defined as population > 1 million), and level of ED (higher versus lower level). We repeated the analysis using propensity-score matched subsets.

Results: Of 54,496 patients with OHCA, we included 5278 (9.7%). Overall survival to admission and to discharge was 20.2% and 6.9%, respectively. ETI and LMA were performed in 250 (4.7%) and 391 (7.4%), respectively. In the full multivariable models using total patients, adjusted survival to admission and discharge were similar for ETI and BVM: OR 0.91 (0.66–1.27) and 1.00 (0.60–1.66), respectively. Adjusted survival to admission and discharge were significantly lower in LMA than BVM: OR 0.72 (0.54–0.95) and 0.52 (0.32–0.85), respectively. In the full multivariable models using propensity matched samples, adjusted survival to admission and discharge were similar for ETI and BVM; OR 1.32 (0.81–2.16) and 1.44 (0.66–3.15), respectively. Adjusted survival to admission was similar for LMA and BVM: OR 0.72 (0.50–1.02). However, survival to discharge was significantly lower for LMA than BVM: OR 0.45 (0.25–0.82).

Conclusions: In Korea, EMT-I placed LMA during ambulance transport was associated with worsened OHCA survival to discharge than BVM. Outcomes were similar between EMT-I endotracheal intubation and bag-valve-mask ventilation.

1. Introduction

1.1. Background

International cardiopulmonary resuscitation (CPR) guidelines emphasize airway management for victims with out-of-hospital cardiac arrest (OHCA).[1–3] Out-of-hospital practitioners in European countries, Canada, Australia, and the United States typically perform airway management using endotracheal intubation (ETI) or alternate airway devices such as the laryngeal mask airway (LMA)

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* Corresponding author at: 101 Daehak-Ro Chongno-Gu, Seoul 110-744, Republic of Korea. Tel.: +82 2 2072 0854; fax: +82 2 741 7855.

E-mail addresses: shinsangdo@medimail.co.kr (S.D. Shin), arent1975@hanmail.net (K.O. Ahn), doctorsong@paran.com (K.J. Song), ipanema2@medimail.co.kr (C.B. Park), ironlyj@gmail.com (E.J. Lee).

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during CPR at most scene. Most Asian countries with single tiered basic Emergency Medical Services (EMS) have only limited experience with out-of-hospital ETI. Rescuers in these systems often use alternate airways such as the LMA.[4–6] In particular, these systems allow the EMTs not to continue CPR until getting the return of spontaneous circulation, but to transport to emergency department (ED) with giving CPR on a moving ambulance.

1.2. Importance

In evolving EMS systems, the choice of airway management device is an important question. Any selected airway devices must balance the potential clinical effectiveness with the limited training resources available when they give CPR during ambulance transport in an evolving EMS system. In addition, it is unclear if ETI is appropriate for countries with evolving EMS systems, where limited experience and training resources may limit any potential benefits. Evaluations of prehospital LMA have focused on process measures such as insertion success/failure, speed of insertion, and feasibility by lower level providers. However, few reports have directly evaluated OHCA outcomes after airway management with the LMA. The LMA is widely accepted in the operating room and has been recommended as an alternative airway for use by basic-level rescuers.[7–9] Few report have investigated the association between airway management and OHCA outcomes in an EMS system where CPR should give during ambulance transport to destination ED.

1.3. Goals of this investigation

The objective of this study was to determine association between airway management technique (ETI, LMA or bag-valve mask ventilation (BVM)) and survival after OHCA in an EMS system with protocol of performing CPR on a moving ambulance.

2. Methods

This was a retrospective cohort study. The study was approved by the Institutional Review Board of the study institution. This study was financially supported by the Center for Disease Control and Prevention of Korea (Korea CDC) (2009).

2.1. Study setting

The Korean EMS system is a single-tier, basic life support (BLS) ambulance service operated by 16 provincial headquarters of the national fire department, which covers a population of about 48 million. Ambulance crews can give CPR at the scene and during transport, and in limited areas can provide care comparable to the intermediate emergency medical technician (EMT-I) level in the US. This includes intravenous fluids, ETI or LMA (classic type) insertion, and certain medications such as epinephrine and atropine under direct medical oversight.[10] Ambulance equipment is standardized by the Korean EMS act. However, prehospital advanced life support is not widely available. In most areas, advanced life support is only available in hospitals.

In Korea, EMTs cannot declare death or stop CPR in the field unless there is return of spontaneous circulation (ROSC). All patients with OHCA are transported to the ED, even those who should have been declared dead in the field. Hospital providers, ED doctors or general physicians will then decide whether or not to terminate resuscitation. This is similar to EMT-basic and intermediate staffed EMS systems in Japan, Taiwan, Hong Kong, and Singapore.[11–14]

Prehospital providers in Korea are classified into two levels; level-1 EMT (EMT-intermediate in US) and level-2 EMT (EMT-basic in US). Prehospital ETI or LMA can be performed only by level-1 EMT under direct or indirect medical oversight. Most level-1 EMTs graduate from EMT schools (a 3–4 year course) and pass a national certification examination. The examination includes airway management using ETI and LMA. To maintain knowledge and skill performance, continuing medical education comprising a four-hour didactic session every year and a 2-month comprehensive clinical training course at ED every 4 years are mandatory. Level-2 EMTs study in fire academies for about 150 h and pass the national level certification examination. Most ambulance crews are composed of two members (first responder with level-1 EMT or level-2 EMT certification) in some rural provinces or three members (level-1, level-2 EMT, and first responder) in most metropolitan–urban provinces.

All EDs are government designated as levels 1–3 based upon each ED's human resources, essential instruments, and equipment. Only Level 1 and level 2 EDs must be covered by emergency physicians 24 h a day. Non-ED facilities, which are small hospital without designated ED, are also used for wildness area. There is currently no regionalized protocol for OHCA. Most patients with OHCA are transported to the nearest hospital regardless of ED service level. Before 2008, few of the 840 EDs adopted therapeutic hypothermia as a post-resuscitation care strategy.

2.2. Data source

The cardiovascular disease surveillance (CAVAS) database was established in 2006 by the Ministry of Health, Welfare, and Family Affairs to improve the outcome of cardiovascular disease in Korea. The Korea CDC is in charge of this database and has provided financial support since 2007. The CAVAS database has three disease entities' data; acute myocardial infarction, acute stroke, and a national observational database of patients with confirmed OHCA. The OHCA database is a population-based cohort separate from EMS medical records.

CAVAS OHCAs were identified from review of ambulance electronic medical records. Ambulance run sheets are electronically stored in each provincial EMS headquarters, operated by the fire department. Trained reviewers visited all hospitals receiving OHCA patients, reviewing medical records to identify clinical information and outcomes according to an Utstein style template.[15] All reviewers received formal training in data abstraction and were aided by a standard manual of operations. When reviewers could not determine information from hospital records (for example, the initial ECG rhythm), an emergency physician reviewed and confirmed the information using primary data sources (for example, the ECG sheet or EMS medical records).

2.3. Study population

We included OHCA data for the study period January 1, 2006 through December 31, 2008. Eligible patients were EMS-assessed and treated OHCA patients with known outcomes, as confirmed by medical record review. We included OHCA of all ages, initial ECG rhythm and cardiac etiology. We enrolled patients receiving CPR at EMS or ED (Resuscitation attempt). Patients not receiving any CPR at both EMS and ED and treated by level 2 EMTs who cannot use ETI or LMA were excluded.

2.4. Interventions

The primary intervention was the method of out-of-hospital airway management, classified as ETI, LMA or BVM. Only EMT level 1 performed ETI. ETI was usually performed through the oral route. Our current protocol indicates that patients with OHCA should be transported to the nearest hospital regardless of ED service level. Our protocol indicates for CPR as follows. First, attach AED pads when you arrive at a suspected arrest victim and give AED shock if indicated (shockable rhythm) or give CPR if indicated (non-shockable rhythm). If the patients are unwitnessed, the protocol encourages EMTs to perform CPR for 2 min before attaching AED pads. EMTs may not follow these options and may attach AED pads first. During attaching AED pads and starting CPR, the other higher level of EMT should perform airway management. The EMT may insert LMA or ETI at the scene/on the stretcher and then take patients to ambulance. In other option, EMT may keep going on performing BVM to ED without inserting LMA or ETI. BVM is mandatory protocol but LMA/ETI is not mandatory. EMTs also can select the ETI or LMA according to their preference. No drug assistance for ETI is allowed. Rescuers confirmed tube placement using physical examination (lung and gastric sounds). End-tidal detectors or capnography are not used.

LMA insertion is included in the Korean national curriculum and was performed using standard techniques. Most EMS agencies use the "Classic" model LMA. Level 1 EMT may use ETI, LMA according to their preference under direct medical oversight. Most ETI and LMA training takes place using airway manikins. Operating room training is not customarily available for EMTs.

2.5. Outcomes and clinical covariates

The primary endpoint was survival to hospital admission. The secondary outcome was survival to hospital discharge. These outcomes were determined from medical record review.

Clinical covariates were determined from the EMS run sheet and included: elapsed time intervals (call to ambulance arrival time to the scene and call to ambulance arrival time to ED), metropolitan population setting (defined as population > 1 million), prehospital defibrillation (using automated external defibrillator), and airway management methods (ETI, LMA, or BVM).

Additional variables obtained from the hospital record included sex, age, witnessed arrest, bystander CPR, initial ECG (ventricular fibrillation/ventricular tachycardia, pulseless electrical activity, asystole, and unknown), and level of ED: higher (level 1/2 ED) versus lower: (level 3 and non-ED facility). We defined data as 'unknown' when the information was not available from medical records regardless of site (e.g. original ECG sheet). For example 'witnessed' was regarded as "unknown" when there was no record about who witnessed the event. The electronic database prevented skipped entries. Missing values from medical record review were categorized as 'unknown'.

2.6. Data and sensitivity analysis

We analyzed the data using multivariable logistic regression, fitting models with both the full cohort as well as propensity score matched subsets. The propensity score is the probability of receiving treatment for a patient with specific prognostic factors.[16] Within propensity score strata, covariates in "intervention group (ETI or LMA)" and "control group (BVM)" groups are similarly distributed. Propensity-based matching is used to select cases and control that have similar combinations of confounders.

We defined separate propensity scores for ETI versus BVM (Model 1) and LMA versus BVM (Model 2). We computed the propensity score by using logistic regression. The independent variables were sex, age, witnessed, bystander CPR, prehospital defibrillation, call to ambulance arrival time at scene, call to ambulance arrival time at ED, metropolitan (defined as population > 1 million), initial ECG, and level of ED (high versus lower level ED). Missing values were categorized as 'unknown' to reduce eligible case loss. To optimize matching, we applied a second 'stepwise logistic regression model' for verification and confirmed the non-significant (even) distribution of potential risk factors into both arms. For example, if there was any significant (uneven) distribution of a risk factor between intervention and control groups, we changed the category of this factor or added a new factor which was associated with the intervention or control groups. We tested the balancing property between propensity score groups.

We calculated propensity scores were to a maximum of 10 decimal places. Patients receiving ETI or LMA (cases) were matched to the closest control (BVM) in each model whose propensity score differed by less than 1×10^{-9}. There was no overlapping of control cases. The number of propensity matched samples was dependent on the proportion of intervention group cases among all eligible patients.

We conducted multivariable logistic regression analyses for both the full cohort as well as the two propensity-score matched subsets. Risk factors were directly selected on the basis of previous literature and included above same variables used for propensity score matching. Adjusted odds ratios (ORs) and 95% confidence intervals (95% CIs) were calculated from multivariates logistic regression models. We tested the goodness-of-fit for final models using Hosmer-Lemeshow chi square test.

3. Results

Of the 54,496 patients with OHCA included in the study, 2096 (3.7%) of unknown outcomes, 20,536 (37.7%) of non-cardiac etiology, 8520 (15.6%) not-treated by EMS providers, 11,121 (20.4%) not-treated by ED physicians, and 7012 (12.9%) treated by level 2 EMTs were excluded (Fig. 1). Of the remaining 5278 patients, 4637 patients (87.9%) were managed with BVM, and 250 (4.7%) with ETI and 391 (7.4%) with LMA.

Overall survival to admission and to discharge was 20.2% and 6.9% in this study population, respectively. The demographic characteristics of the patients in each airway management group are summarized in Table 1. Response time, metropolitan setting, witnessed arrest, bystander CPR, shockable rhythm, and proportion in ED level were different for LMA group or ETI group compared with BVM. Survival to admission rate was 22.0% in ETI group, 20.5% in LMA group, and 20.1% in BVM group, respectively. Survival to discharge rate was 8.0% in ETI group, 5.6% in LMA group, and 7.0% in BVM group, respectively.

Demographic characteristics were similar between propensity-matched groups (Table 2). Survival to admission and to discharge was similar between ETI and BVM group while survival to discharge of LMA group was lower than BVM group ($p = 0.04$).

In the full multivariable models using total patients ($N = 5278$), adjusted survival to admission and discharge were similar for ETI and BVM; OR 0.91 (0.66–1.27) and 1.00 (0.60–1.66), respectively. Adjusted survival to admission and discharge were significantly lower in LMA than BVM: OR 0.72 (0.54–0.95) and 0.52 (0.32–0.85), respectively.

The propensity matched samples were selected for ETI and BVM group ($N = 248$ for both each group) and for LMA and BVM ($N = 386$ for each group). In the full multivariable models using propensity matched samples, adjusted survival to admission and discharge were similar for ETI and BVM; OR 1.32 (0.81–2.16) and 1.44 (0.66–3.15), respectively. Adjusted survival to admission was similar for LMA and BVM: OR 0.72 (0.50–1.02). However, survival to discharge was significantly lower for LMA than BVM: OR 0.45 (0.25–0.82) (Table 3).

4. Limitations

This study is retrospective and observational and not the result of a prospective randomized trial. Despite our use of multivariable

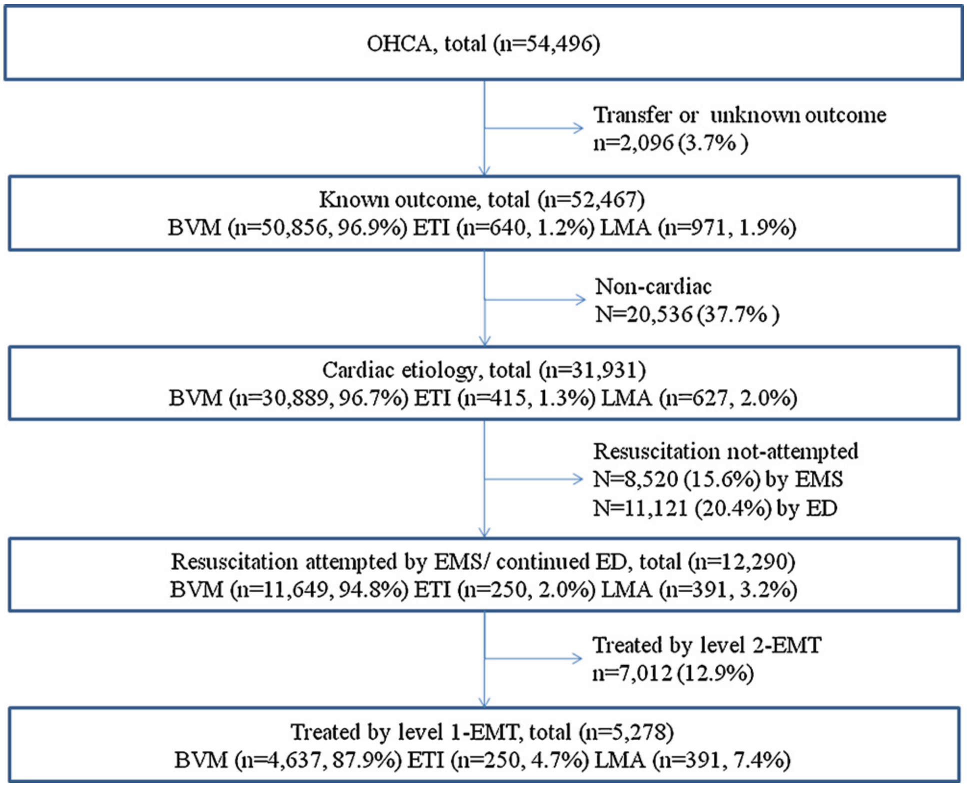

Fig. 1. Study population and airway management. OHCA: out-of-hospital cardiac arrest; BVM: bag-valve mask ventilation; ETI: endotracheal intubation; LMA: laryngeal mask airway ventilation; ED: emergency department; EMS: emergency medical service; EMT: emergency medical technician.

Table 1
Demographic findings by airway management.

Risk factors	ETI		LMA		BVM		Total	
	N	%	*N*	%	*N*	%	*N*	%
Total, *N*	250		391		4637		5278	
Gender, *N* (%)								
Male	160	64.0	270	69.1	3154	68.0	3584	67.9
Female	90	36.0	121	30.9	1483	32.0	1694	32.1
Age (year), mean ± std	61.7 ± 17.0		61.0 ± 16.9		60.8 ± 17.4		60.9 ± 17.3	
Call to arrival at the scene (min), mean ± std	6.9 ± 3.8		6.8 ± 3.8		6.9 ± 4.5		6.9 ± 4.4	
Call to arrival at ED (min), mean ± std	24.9 ± 11.4		23.2 ± 10.3		24.4 ± 15.5		20.0 ± 9.9	
Urbanization, *N* (%)								
Metropolitan	119	47.6	178	45.5	3,231	69.7	3,528	66.8
Non-metropolitan	131	52.4	213	54.5	1,406	30.3	1,750	33.2
Witnessed, *N* (%)								
No	148	59.2	240	61.4	2636	56.8	3,024	57.3
Yes	83	33.2	136	34.8	1711	36.9	1,930	36.6
Unknown	19	7.6	15	3.8	290	6.3	324	6.1
Bystander CPR, *N* (%)								
No	57	22.8	78	19.9	1045	22.5	1180	22.4
Yes	10	4.0	16	4.1	125	2.7	151	2.9
Unknown	183	73.2	297	76.0	3467	74.8	3947	74.8
Prehospital defibrillation								
No	85	34.0	109	27.9	1626	35.1	1820	34.5
Yes	27	10.8	61	15.6	244	5.3	332	6.3
Unknown	138	55.2	221	56.5	2767	59.7	3126	59.2
Initial ECG, *N* (%)								
VF or pulseless VT	32	12.8	62	15.9	436	9.4	530	10.0
PEA	19	7.6	32	8.2	244	5.3	295	5.6
asystole	126	50.4	225	57.5	2722	58.7	3073	58.2
Unknown	73	29.2	72	18.4	1235	26.6	1380	26.1
ED level, *N* (%)								
Level 1/level 2	186	74.4	320	81.8	2831	61.1	3337	63.2
Level 3/level 4	64	25.6	71	18.2	1806	38.9	1941	36.8
Survival								
To admission, *N* (%)	55	22.0	80	20.5	933	20.1	1068	20.2
To discharge, *N* (%)	20	8.0	22	5.6	323	7.0	365	6.9

ETI, endotracheal intubation; LMA, laryngeal mask airway ventilation; BVM, bag-valve mask ventilation; ED, emergency department; CPR, cardiopulmonary resuscitation; VF, ventricular fibrillation; VT, ventricular tachycardia; PEA, pulseless electrical activity; EMT, emergency medical technician; *N*, number; %, percent.

Table 2
Demographic findings of propensity score-based matched samples; BVM vs. ETI (Model 1), BVM vs. LMA (Model 2).

Risk factors	Model 1					*p*-Value	Model 2					*p*-Value
	Total	ETI		BVM			Total	LMA		BVM		
	N	*N*	%	*N*	%		*N*	*N*	%	*N*	%	
Total, *N*	496	248		248			772	386		386		
Gender, *N* (%)						0.15						0.64
Male	163	89	35.9	74	29.8		540	267	69.2	273	70.7	
Female	333	159	64.1	174	70.2		232	119	30.8	113	29.3	
Age (year), mean ± std		61.4 ± 17.0		61.7 ± 17.0		0.89		60.9 ± 16.9		60.6 ± 16.9		0.80
Call to arrival at the scene (min), mean ± std		6.9 ± 4.1		6.9 ± 3.9		0.74		6.8 ± 3.8		6.9 ± 4.8		0.73
Call to arrival at ED (min), mean ± std		24.9 ± 12.9		24.9 ± 11.4		0.98		23.1 ± 10.0		23.4 ± 11.3		0.74
Urbanization, *N* (%)						0.42						0.28
Metropolitan	245	118	47.6	127	51.2		437	211	54.7	226	58.5	
Non-metropolitan	251	130	52.4	121	48.8		335	175	45.3	160	41.5	
Witnessed, *N* (%)						0.89						0.52
No	290	147	59.3	143	57.7		461	238	61.7	223	57.8	
Yes	169	82	33.1	87	35.1		280	134	34.7	146	37.8	
Unknown	37	19	7.7	18	7.3		31	14	3.6	17	4.4	
Bystander CPR, *N* (%)						0.21						0.36
No	122	57	23.0	65	26.2		154	77	19.9	77	19.9	
Yes	14	10	4.0	4	1.6		25	16	4.1	9	2.3	
Unknown	360	181	73.0	179	72.2		593	293	75.9	300	77.7	
Prehospital defibrillation						0.67						0.28
No	177	85	34.3	92	37.1		208	109	28.2	99	25.6	
Yes	49	27	10.9	22	8.9		107	59	15.3	48	12.4	
Unknown	270	136	54.8	134	54.0		457	218	56.5	239	61.9	
Initial ECG, *N* (%)						0.38						0.22
VF or pulseless VT	66	32	12.9	34	13.7		103	61	15.8	42	10.9	
PEA	45	19	7.7	26	10.5		61	31	8.0	30	7.8	
Asystole	230	124	50.0	106	42.7		456	223	57.8	233	60.4	
Unknown	155	73	29.4	82	33.1		152	71	18.4	81	21.0	
ED level, *N* (%)						0.40						0.46
Level 1/level 2	378	185	74.6	193	77.8		624	316	81.9	308	79.8	
Level 3/level 4	118	63	25.4	55	22.2		148	70	18.1	78	20.2	
Survival												
To admission, *N* (%)	104	55	22.2	49	19.8	0.51	174	79	20.5	95	24.6	0.17
To discharge, *N* (%)	37	20	8.1	17	6.9	0.61	59	22	5.7	37	9.6	0.04

ETI, endotracheal intubation; LMA, laryngeal mask airway ventilation; BVM, bag-valve mask ventilation; ED, emergency department; CPR, cardiopulmonary resuscitation; VF, ventricular fibrillation; VT, ventricular tachycardia; PEA, pulseless electrical activity.

Table 3
Odds ratios (ORs) and 95% confidence intervals (95% CIs) by airway management method on the hospital outcome using logistic regression model in total patient group and propensity score-based matched patients.

Study group	Survival to admission						Survival to discharge				
	Total	Survival		Adjusted			Survival		Adjusted		
		N	%	OR	95% CI		*N*	%	OR	95% CI	
Total patient group[†]											
Total	5278	1068	20.2				365	6.9			
BVM	4637	933	20.1	1.00			323	7.0	1.00		
ETI	250	55	22.0	0.91	0.66	1.27	20	8.0	1.00	0.60	1.66
LMA	391	80	20.5	0.72	0.54	0.95	22	5.6	0.52	0.32	0.85
Propensity score-based matched patient group											
Model 1 (BVM vs. ETI)[‡]											
Total	496	104	21.0				26	3.6			
BVM	248	49	19.8	1.00			17	6.9	1.00		
ETI	248	55	22.2	1.32	0.81	2.16	20	8.1	1.44	0.66	3.15
Model 2 (BVM vs. LMA)[¶]											
Total	772	174	22.5				59	7.6			
BVM	386	95	24.6	1.00			37	9.6	1.00		
LMA	386	79	20.5	0.72	0.50	1.02	22	5.7	0.45	0.25	0.82

ETI, endotracheal intubation; LMA, laryngeal mask airway ventilation; BVM, bag-valve mask ventilation.

[†] Adjusted for sex, age, witnessed, prehospital defibrillation, bystander cardiopulmonary resuscitation (CPR), call to ambulance arrival time to the scene, call to ambulance arrival time to ED, initial ECG, and metropolitan (defined as population > one million). The area under the receiver operating characteristic curve (AUC) for survival to admission and to discharge was 0.704 and 0.760 for total group, respectively. Hosmer Lemeshow chi square for goodness-of-fit was 10.7 (p value = 0.22) and 8.4 (p value = 0.39), respectively.

[‡] Adjusted for sex, age, witnessed, prehospital defibrillation, bystander cardiopulmonary resuscitation (CPR), call to ambulance arrival time to the scene, call to ambulance arrival time to ED, initial ECG, and metropolitan (defined as population > 1 million). The area under the receiver operating characteristic curve (AUC) for survival to admission and to discharge was 0.791 and 0.866 in Model 1, respectively. Hosmer Lemeshow chi square for goodness-of-fit was 11.8 (p-value = 0.16) and 4.5 (p-value = 0.81), respectively.

[¶] Adjusted for sex, age, witnessed, prehospital defibrillation, bystander cardiopulmonary resuscitation (CPR), call to ambulance arrival time to the scene, call to ambulance arrival time to ED, initial ECG, and metropolitan (defined as population > 1 million). The area under the receiver operating characteristic curve (AUC) for survival to admission and to discharge was 0.685 and 0.783 in Model 2, respectively. Hosmer Lemeshow chi square for goodness-of-fit was 3.6 (p-value = 0.89) and 9.8 (p-value = 0.28), respectively.

techniques, there may be unknown confounders that could not be adequately adjusted for. We included most eligible patients for study, but 3.7% of patients were excluded due to unknown final outcomes, which could have influenced our findings.

This study involved a single tiered intermediate life support service system in Korea. Advanced life support (ALS) interventions in Korea are extremely uncommon. Many western systems such as North America, Europe, and Australia provide comprehensive ALS to OHCA victims in the field, which is different from the Asian setting. Extrapolation of this result to ALS systems should be done with caution due to this difference. Although this study is comparable to other agency systems with similar service levels, it may not be directly comparable to more mature EMS systems in North America.

Our data were derived from patient care reports. We had no method for independent confirmation of field airway technique or events. The EMTs in this studied also received only limited airway management training. Most level 1 EMTs in Korea have few chances to maintain their skills for ETI or LMA after passing the national examination. The national government EMS headquarters provides 1-day courses for airway management composed of 4 h didactic sessions and a 4-h skill session with 16 regional collaborating emergency centers. However this course is not mandatory for level 1 EMTs. We could not analyze how well ET or LMA was performed by EMS providers because of lack of information such as the number of ET attempts, failure rates, procedure times for LMA, or proportion of misplacement of LMA.

Another considerable limitation would be that we had no information whether airway management was associated with poorer quality of CPR and more CPR interruptions. We also had no information on post-resuscitation care, which may have had a major effect on outcomes. Our analysis included presumed cardiac OHCA, excluding trauma cases. We cannot generalize the result to non-cardiac etiology.

5. Discussion

While EMS providers in the United States commonly perform ETI on victims of cardiac arrest, practitioners in lesser trained countries often use alternate airways such as the LMA. The relative associations of these devices with OHCA outcomes are undefined. In this national assessment of OHCA from Korea, we found that compared with BVM, ETI and LMA were not associated with adjusted survival to hospital admission. ETI was also not associated with adjusted survival to discharge. However, compared with BVM, LMA was associated with slightly lower adjusted survival to hospital discharge.

Generally speaking, previous studies showed benefit in terms of faster insertion in LMA than ETI. A scenario-based study showed much shorter time to establish ventilation in LMA compared with ETI (18 versus 26 s in sitting scenario, 27.5 versus 57 s in supine scenario, and 17 versus 39 s in on site scenario, respectively).[17] To establish ventilation using specific type of LMA (Ctrack), less than 15 s was needed in a small prehospital trial ($n = 16$) with very higher success rate (94%).[18] Many Asian EMS systems encourage for EMTs to use LMA for prehospital airway management method.

The reasons for the poorer LMA outcomes are unclear in this study. The first possible explanation could be device related problems. The LMA was developed to allow for blind insertion and to overcome limitations like dislodgement.[4,5] In this study, the first generation of LMA (classic LMA) was used because the later generation of LMA was not available yet. It is thought to be easy for lower level service providers to insert safely. However, it is very difficult to insert the LMA to a defined level during chest compressions on a moving ambulance. LMA dislodgement is a possibility during patient transport and care, but it is unclear how different degrees of dislodgement impact ventilations in this context. Higher and lower level of EMT should change their positions and roles of giving chest compression and maintaining airway and ventilation when they transport the patients over about 20 min. Lower level of EMTs may give hyperventilation when they give CPR on a moving ambulance, because lower level of EMTs has few clinical experience or training for LMA airway and ventilation.

Another possible explanation could be interruptions in CPR chest compression resulting from LMA insertion. Prior studies have found more than 1–1/2 min of CPR interruptions resulting from paramedic ETI efforts. Although CPR interruptions should be shorter with the LMA due to fast insertion time,[17,18] a prior study found that over 20 s of CPR interruption may be required for LMA insertion in pediatric simulation model.[19] Inadequate LMA procedural experience may also play a role. Prior studies have highlighted the difficulty of ensuring adequate paramedic ETI procedural experience.[20,21] When we performed additional analysis, we found EMTs had very little experience of LMA use over 2 years, with EMT's performing a median of 2 (IQR 1–3) LMA insertions for 2 years. There are no data indicating the optimal number of LMA procedures for EMT-intermediates to maintain procedural proficiency.

Alternate airway methods during ambulance CPR for OHCA are important for developing EMS systems, given the constraints of our limited skill and training resources. Chest compression only CPR has been recommended for basic life support by lay persons or basic providers in some communities.[22–24] To avoid inappropriate ventilation and to minimize interruptions to chest compression on moving ambulances, chest compression only CPR may be an alternative strategy in very low service level EMS areas. Better-designed alternative airway devices can also be considered for evolving EMS systems.

In a meta analysis on prehospital alternative airway management, success rate was much higher in King LT (96.5%, 95% confidence interval; 71.2–99.7%) than LMA (87.4%, 95% confidence interval; 79.0–92.8%).[25] The King Laryngeal Tube (LT) airway is extremely popular in the United States. However we did not have access to the King LT airway in this study. A prospective multicenter study, non-randomized control trial compared arterial blood gas analysis on hospital admission of patients resuscitated by EMS personnel with a BVM with those using a LMA in witnessed cardiac-verified out-of-hospital ventricular fibrillation (VF) or pulseless ventricular tachycardia showed higher pH in LMA group than BVM group while no different PaCO2 and PaO2. From this study, LMA did not greatly benefit the respiratory status of patients.[26]

ETI has been a crucial component of resuscitation in mature EMS systems. However ETI contains many perils such as tube misplacement or dislodgement, multiple laryngoscopy attempts and interruptions of chest compression.[27] Advanced airway methods (LMA and ETI) were found to be associated with decreased survival to hospital discharge among adult nontraumatic OHCA patients in recent studies.[28,29] Many US EMS agencies have switched from ETI to the King LT airway to facilitate CPR continuity during airway management efforts. In contrast, evolving EMS systems in Asia have been slow to adopt ETI, in particular on moving ambulances. The limited training resources have forced these agencies to embrace other methods of airway management. In the context of our type of EMS system, our study presents evidence that LMA use may adversely impact patient outcomes. Additional studies are needed to confirm or refute this finding.

Finally, few evidences on CPR during ambulance transport are there. In our system, all patients with OHCA should be mandatory transported to ED with receiving CPR at the scene and during transport. There are many issues for optimal quality CPR as followings. How long do EMTs stay and give CPR at the field before departure to ED? Where is the best place for inserted LMA or ETI between on scene or on stretcher cart or on ambulance? How long time intervals need change of EMTs to perform CPR during ambulance transport? These issues were neglected in previous literatures. Further investigations would be added to improve the quality of CPR during ambulance transport.

6. Conclusion

In this Korean national cohort, airway management technique during ambulance transport was not associated with adjusted survival to hospital admission after OHCA. ETI was also not associated with adjusted survival to hospital discharge. However, LMA was associated with worsened adjusted survival to hospital discharge compared with BVM ventilation.

Conflict of interest statement

All authors (Shin S.D., Ahn K.O., Song K.J., Park C.B., and Lee E.J.) are not related with any other conflicts of interest in this study.

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