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Laryngeal mask airway in out-of-hospital cardiac arrest

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INTRODUCTION

Despite the advances in medical care over the years, out-of-hospital cardiac arrest (OHCA) remains a major public health concern. The prognosis of OHCA is grave and only 2.3% survived to discharge.[1] Pre-hospital emergency care has an important impact on its outcome. The Resuscitation Council of Hong Kong and the ambulance services in Hong Kong follow the American Heart Association guideline on cardiac arrest, which recommends that either a bag-mask device (BVM) or an advanced airway (i.e. endotracheal tube or supraglottic airway device) may be used for oxygenation and ventilation during cardiopulmonary resuscitation (CPR).[2] In the recent decades, supraglottic airway devices are gaining popularity in pre-hospital airway management.

Laryngeal mask airway (LMA) is one of the supraglottic airway devices widely used worldwide. Theoretically, advanced airway management provides better ventilation than basic airway management, which improves oxygen delivery to the brain tissues and hence neurological outcome. Our study aims to investigate the benefits of LMA in OHCA victims, compared to BVM ventilation with oropharyngeal airway (OPA) in the setting of an Asian-Chinese population.

METHODS

This is an observational study based on prospectively collected data in a regional cardiac arrest registry, which recruits all OHCA attending the three emergency departments (ED) in a territory with a population of 1.1 millions in Hong Kong, namely Tuen Mun Hospital, Pok Oi Hospital and Tin Shui Wai Hospital. In Hong Kong, the emergency medical services (EMS) is a one-tier system and patients are delivered to the nearest ED. Once cardiac arrest is confirmed, resuscitation would be started by EMS following Basic Life Support protocol. Endotracheal intubation would not be performed by EMS.

The choice of ventilation through LMA or BVM is at the discretion of each attending EMS personnel following the EMS protocol. LMA is indicated for all OHCA patients aged 12 or above. It is contraindicated in patients with (1) unrelieved upper airway obstruction (e.g. foreign body), (2) major local pathologies at pharynx/larynx, or (3) tumour, abscess, hematoma or oedema in upper airway. The model of LMA Supreme is adopted. LMA would be removed if ventilation is unsuccessful (e.g. obvious air-leak, poor air entry or resistance), or if there is risk of aspiration (e.g. continuous regurgitation). LMA would not be applied if the jaw opening is too small to allow insertion or the distance from scene to hospital is very short, which is decided by the EMS personnel in-charge. In successful insertion, ventilation synchronising with chest compression would be provided through manual bagging via LMA (i.e. 30:2 compression-to-breath ratio). The number of attempt in LMA insertion is not controlled. If LMA insertion fails or is found not suitable, BVM ventilation with an OPA would be applied. Those with attempted LMA insertion but fails would not be regarded as LMA group in the study.

Non-traumatic OHCA adult patients who aged 18 or above with active resuscitation by EMS from August 1, 2010 to July 31, 2017 were included. Exclusion criteria included those with traumatic arrest, return of spontaneous circulation (ROSC) before EMS arrival, regaining consciousness contraindicating artificial airway, postmortem changes, advance directive of Do-Not-Attempt CPR, or termination of resuscitation before hospital arrival or in ED. Patients with pre-existing tracheostomy, undocumented pre-hospital airway management, no pre-hospital airway or loss of follow-up were also excluded.

The data collection was performed prospectively in the cardiac arrest registry. Pre-hospital parameters were transcribed from ambulance records. Data throughout the resuscitation process was collected by standardised data forms, which were completed by the emergency physician in-charge immediately after the resuscitation to minimize recall bias. The

data accuracy was confirmed by verification between pre-hospital and hospital databases. Outcome parameters were verified with data from the death registry.

Data was then collected from the registry according to the Utstein style,[3] including gender, age, presumed aetiology of arrest, witnessed status, bystander CPR, initial pre-hospital cardiac rhythm, pre-hospital defibrillation, technique of pre-hospital airway management, times of EMS call and arrival to patients' side by EMS. Charlson comorbidity index was calculated from patients' previous medical history to reflect premorbid comorbidity status.[4] Missing values were categorised as unknown to reduce eligible case loss.

Regarding the aetiology of cardiac arrest, cardiac causes were presumed in patients with a witnessed arrest, a shockable rhythm, electrocardiographic evidence of myocardial infarction, preceding chest pain, or those confirmed by autopsy. Non-cardiac causes included poisoning, intracranial lesions, sepsis, electrolyte disturbances, respiratory/asphyxial causes or other identifiable causes based on clinical findings or autopsy. The judgment was made by the attending emergency physician.

The study was performed in compliance to the Declaration of Helsinki. Ethics approval was obtained from the local institutional review board (reference number NTWC/CREC/18024).

The primary outcome was survival to hospital discharge with good neurological status, defined as Glasgow-Pittsburgh cerebral performance category 1 (good performance) or 2 (moderate disability). The other categories – 3 (severe cerebral disability), 4 (coma/vegetative state) and 5 (death/brain death) – were regarded as unfavourable neurological outcomes.[3] The secondary outcomes were survival to hospital discharge and ROSC. ROSC was defined as return of a spontaneous circulation with a palpable pulse for at least 20 minutes without chest compressions, and with an organized spontaneous ECG rhythm followed by a measurable blood pressure.

This study compared outcomes between LMA and BVM ventilation with OPA in patients with OHCA. Continuous parameters were described as mean and median according to the distribution, and subsequently compared with independent t-test or Mann Whitney U test as appropriate. Categorical variables were expressed as proportions and compared with Chi-square test. For the three outcome parameters, unadjusted crude odds ratio and adjusted odds ratio in unconditional logistic regression were presented. Confounding variables entered into the logistic regressions were listed in Table 1. Stratified analysis for the groups of ROSC before hospital arrival, presumed aetiology (cardiac versus non-cardiac), initial rhythm, witnessed state were performed.

Pre-hospital airway management was decided by EMS and was not randomly assigned. Therefore, a propensity matching analysis was also performed. Propensity scores were calculated to 10 decimal spaces with the predicted probabilities of receiving LMA or BVM. Logistic regression was modelled with the airway adopted as the dependent variable, predicted by a number of independent predictors listed in Table 1. Patients received LMA were matched to the closest control in the BVM group with propensity score differed by <0.001 with no overlapping cases. In the propensity-matching analysis, both unadjusted and adjusted odds ratios were contrasted between the two airway groups.

Statistical software employed was IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp, Released 2013. All statistical tests were two-tailed with type 1 error rate of < 5%. Binary logistic regression was adopted. We assumed that neurologically favourable survival was 1.5-2%[1] and 30% patients received LMA. The power was chosen as 80% while the level of significance was decided as 5%. As the effect size (odds ratio) taken for LMA was 0.38,[5] a sample size of 3580 would be required for a two-tailed observation. The sample size was calculated with PASS 2011 software (PASS 11. NCSS, LLC. Kaysville, Utah, USA. www.ncss.com).

RESULTS

A total of 5213 OHCA patients were reviewed. Of those 4558 adult patients with non-traumatic cardiac arrest resuscitated by EMS, 122 with pre-hospital airway not documented, 287 with no pre-hospital airway, 31 with existing tracheostomy and 342 not resuscitated in ED were excluded. Among the remaining 3776 included in the analysis, 745 (19.7%) received LMA, whereas 3031 (80.3%) received BVM ventilation through OPA.

Table 1 shows the baseline characteristics of all OHCA while Table 2 presents the outcomes of the two airway groups. Overall, the rates of ROSC, survival to hospital discharge and neurological favourable outcome were apparently lower in the LMA group (ROSC 28.2%; survival to discharge 1.6%; neurologically favourable survival 1.5%) compared to the BVM group (ROSC 30.6%; survival to discharge 2.3%; neurologically favourable survival 1.8%). Regarding outcome of ROSC and neurologically favourable survival, there was a generally observed trend of inferior outcome with LMA but it did not achieve statistical significance (Table 2). In the stratified analysis, there was no observed difference in the two airway groups in terms of neurologically favourable survival.

In the propensity score matched analysis, 745 patients with comparable demographic and clinical characteristics were included in each group, and the results of logistic regression models was shown in Figure 1. In the unadjusted model, there was no significant difference between LMA and BVM regarding rates of ROSC, survival to hospital discharge and neurologically favourable survival. After adjustment for the confounding variables, LMA was demonstrated to associate with a lower rate of ROSC (OR 0.47; 95% CI 0.32-0.66; p=0.025) and a lower survival to hospital discharge rate (OR 0.20; 95% CI 0.05-0.81; p=0.031). There was no statistical significance between LMA and BVM on favourable neurological survival.

DISCUSSION

Our results demonstrated a significant lower hospital discharge rate among non-traumatic OHCA patients with pre-hospital LMA use than those with BVM ventilation in the adjusted full cohort (OR 0.338, *p*=0.048) and in propensity-matched patients (OR 0.20, p=0.031). LMA also associated with a lower ROSC rate in multivariable models using propensity score matched samples (OR 0.47; *p*=0.025). The study revealed a trend towards a negative association of LMA on favourable neurological outcome, although a statistical significance was not achieved (OR 0.378, p=0.128). Our results echoed the findings of previous studies by Hanif,[6] Mcmullan[7] and Shin,[8] which demonstrated inferior outcomes of pre-hospital supraglottic airway on survival to hospital discharge and neurological-intact survival. A large nationwide population-based study by Hasegawa[5] also had consistent results, despite a contradicting result in Park's study,[9] which consisted of a small number of samples. The finding was similar in Pan-Asian countries in a recent study, in which advanced airway was found to be associated with a lower OHCA survival.[10]

There are several explanations proposed for our findings. To begin with, good-quality chest compression takes priority over ventilation. The European Resuscitation Council and ACLS guideline emphasised the importance of chest compressions more than rescue breaths in cardiac arrest.[2,11] A prospective randomized trial study by Svensson[10] showed similar survival rates from witnessed adult OHCA with either compression-only CPR or CPR with both compressions and rescue breaths. This illustrated that ventilation is less important in the initial period of resuscitation, suggesting that attempt to provide better ventilation in pre-hospital phase, such as pre-hospital LMA insertion may not be beneficial if there is a subsequent delay in chest compression, timely defibrillation and early hospital care.

Besides, our study revealed a significantly longer time from EMS call to hospital arrival in patients receiving LMA than those with BVM ventilation (Table 1). The possible accountable

causes could be LMA insertion causing delay to hospital, or reversely LMA insertion was more liberally performed for those with expected longer travel time to hospital. In an urban setting like Hong Kong, where hospitals were of close proximity, the use of LMA might be less efficient as it might take a longer time and lead to a prolonged pre-hospital phase. Another possible explanation is device-related problems resulting from LMA use, such as failed LMA insertion, failure to ventilate, or LMA dislodgement during transport, leading to a poorer outcome. According to the EMS protocol, LMA insertion should be performed with ongoing chest compressions. Further investigations on any disturbance of good-quality CPR or defibrillation due to LMA insertion is required.

It was postulated that OHCA due to non-cardiac causes, especially asphyxial aetiology, may benefit theoretically more from better pre-hospital ventilation. However, in subgroup analysis of our study, no outcome difference was demonstrated between LMA and BVM among OHCA patients with non-cardiac causes (Table 2). This result was similar to Fukuda's study,[12] which demonstrated that advanced airway management was associated with poor neurological outcomes in adult OHCA caused by respiratory disease. For patients with pre-hospital ROSC, the outcomes of patients with LMA and BVM ventilation were very similar. Likewise, LMA and BVM ventilation contributed to similar outcomes irrespective of the initial rhythm and the witnessed status in OHCA. It suggested that LMA was not superior than BVM in OHCA with either cardiac or non-cardiac causes, and those with either early or prolonged arrest.

There are several limitations in our study. First, as an observational study, our study could not demonstrate a direct causal relationship between pre-hospital airway management and the outcomes in OHCA. Besides, randomisation and blinding were not possible and selection bias and performance bias by the EMS may occur. A randomised controlled trial may be conducted in the future to overcome this. Second, different from the usual practice recommended by the ACLS guideline that unsynchronized compression ventilation with 1 breath every 6 seconds

should be applied after an advanced airway is in place,[2] the EMS performed synchronous ventilation with chest compression in CPR after pre-hospital LMA insertion in our study. With chest compression being withheld for ventilation, the outcome might potentially be affected in patients receiving LMA ventilation.

Third, we did not have data regarding the failure rate of LMA insertion and the number of attempts at LMA insertion, which might be an important confounding factor. It was presumed that the EMS personnel were proficient at LMA use as they have received relevant training. However, there might be difference among their competency causing potential bias, which would be evaluated by actual observations of the ambulance crew in performing such procedures by experienced auditors in future studies. We also lacked information regarding reasons of LMA not being used. Compared with those who failed LMA insertion and were subsequently given BVM ventilation, patients who were given BVM directly might take a shorter procedure time and a better outcome might be demonstrated if they were analysed as a separate group. Moreover, possible complications such as air leak and LMA dislodgement during transport, could potentially cause a poorer performance and underestimation on the outcomes of LMA use. Similarly, it is difficult to measure the quality of BVM, especially during transport, which a good BVM seal might be disturbed due movement and therefore affecting effective ventilation.

Fourth, we could only presume that the longer time from EMS call to hospital arrival for LMA patients may associate with the LMA procedure. There was no data on the exact EMS on-scene time. Although it was difficult and possibly not feasible to measure the LMA procedure time during CPR, we would have a more precise estimation of it from the on-scene time, which in turn could be obtained by recording the time of EMS leaving the scene to hospital. Finally, our sample size was not adequate to demonstrate a statistically significant result in favourable neurological outcome in OHCA victims. A larger number of patients would

be needed to show a more valid result.

In conclusion, in adult non-traumatic patients with OHCA in Hong Kong, the use of pre-hospital LMA associated with a lower rate of ROSC and survival to discharge, with no statistically significant difference observed in the neurological outcome of the survivors.

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Table 1. Baseline characteristics of out-of-hospital cardiac arrest in the complete cohort based on the initial pre-hospital airway

Characteristics	All (N=3776)	LMA (N=745)	BVM ventilation (N=3031)	p value
Age (mean, SD)	74.1, 16.2	72.8, 16.8	74.6, 16.4	0.018^
Gender, male	2171 (57.5%)	455 (61.1%)	1716 (56.6%)	0.027^
Presumed etiology of cardiac arrest				
Cardiac	1135 (30.1%)	257 (34.5%)	878 (29%)	0.003^
Non-cardiac	702 (18.6%)	112 (15%)	590 (19.5%)	0.005^
Unknown	1939 (51.4%)	376 (50.5%)	1563 (51.6%)	0.591
Initial cardiac rhythm				
VF / VT	376 (10%)	79 (10.6%)	297 (9.8%)	0.511
PEA / asystole	3400 (90%)	666 (89.4%)	2734 (90.2%)	--
Witnessed status				
No witness	2174 (57.6%)	454 (60.9%)	1720 (56.4%)	0.043^
Witnessed by layperson	1486 (39.4%)	278 (37.3%)	1208 (39.9%)	0.204
Witnessed by EMS	116 (3.1%)	13 (1.7%)	103 (3.4%)	0.019^
Bystander CPR	840 (22.2%)	147 (19.7%)	693 (22.9%)	0.063
Public access defibrillation by bystander	37 (1%)	6 (0.8%)	31 (1%)	0.589
Defibrillation by EMS	555 (14.7%)	122 (16.4%)	433 (14.3%)	0.150
Time from EMS call to arrival by patients' side (median, IQR), min	8 (6-11)	8 (6-11)	8 (6-11)	0.216
Time from EMS call to hospital arrival (median, IQR), min	26 (23-31)	28 (24-32)	26 (22-31)	< 0.001^
Charlson Comorbidity Index (median, IQR)	4 (3-7)	4 (3-7)	5 (3-7)	0.019^

Abbreviations: BVM=Bag-valve-mask; VF=ventricular fibrillation; VT=pulseless ventricular tachycardia; PEA=pulseless electricity activity; ROSC=return of spontaneous circulation; EMS=emergency medical service; CPR=cardiopulmonary resuscitation; SD=standard deviation; IQR=interquartile

^ = p-values that are statistically significant

Table 2. Unconditional logistic regression for outcomes comparing initial pre-hospital airway management in the complete cohort

Model	All patients (N=3776)	LMA (N=745)	BVM ventilation (N=3031)	OR of LMA vs BVM (95% CI)	p value
Return of spontaneous circulation	1137 (30.1%)	210 (28.2%)	927 (30.6%)		
Unadjusted				0.891 (0.746-1.064)	0.202
Adjusted for confounding variables[#]				0.913 (0.721-1.156)	0.449
Survival to hospital discharge	82 (2.2%)	12 (1.6%)	70 (2.3%)		
Unadjusted				0.692 (0.373-1.284)	0.241
Adjusted for confounding variables[#]				0.338 (0.115-0.991)	0.048*
Neurologically favorable survival	67 (1.8%)	11 (1.5%)	56 (1.8%)		
Unadjusted				0.796 (0.415-1.527)	0.492
Adjusted for confounding variables[#]				0.378 (0.108-1.324)	0.128
Stratified analysis					
ROSC before hospital arrival	45/123 (36.6%)	7/19 (36.8%)	38/104 (36.5%)	1.013 (0.368-2.793)[*]	0.980[*]
Presumed cardiac etiology	55/1135 (4.8%)	11/257 (4.3%)	44/878 (5%)	0.436 (0.118-1.605)[#]	0.212[#]
Presumed non-cardiac etiology	9/702 (1.3%)	1/111 (0.9%)	8/591 (1.4%)	0.648 (0.080-5.236)[*]	0.682[*]
Initial rhythm – VF/VT	49/376 (13%)	7/78 (9%)	42/298 (14.1%)	0.601 (0.259-1.395)[*]	0.232[*]
Initial rhythm – PEA/asystole	18/3400 (0.5%)	4/667 (0.6%)	14/2733 (0.5%)	1.285 (0.245-6.733)[#]	0.767[#]
Not witnessed	14/2170 (0.6%)	2/453 (0.4%)	12/1717 (0.7%)	0.630 (0.141-2.825)[*]	0.543[*]
Witnessed by layperson	47/1486 (3.2%)	8/278 (2.9%)	39/1208 (3.2%)	0.407 (0.087-1.898)[#]	0.253[#]
Witnessed by EMS	6/116 (5.2%)	1/13 (7.7%)	5/103 (4.9%)	1.633 (0.176-15.177 [*]	0.653[*]

[#]Adjustment for confounding variables including age, gender, presumed etiology, initial cardiac rhythm, bystander CPR, witnessed status, defibrillation by bystander and EMS, patient's comorbidity (Charlson comorbidity index), time from EMS call to arrival to patients' side, time from EMS call to hospital arrival. [*]Unadjusted odds ratio and p value were reported due to inability to predict in multivariate model with low even

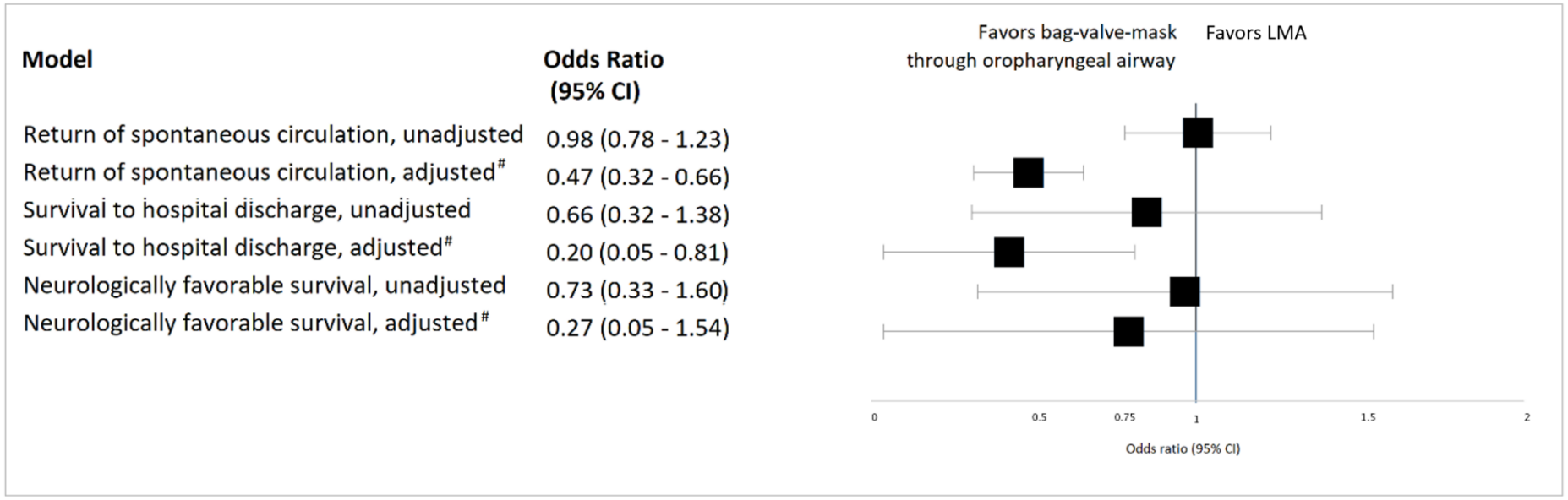
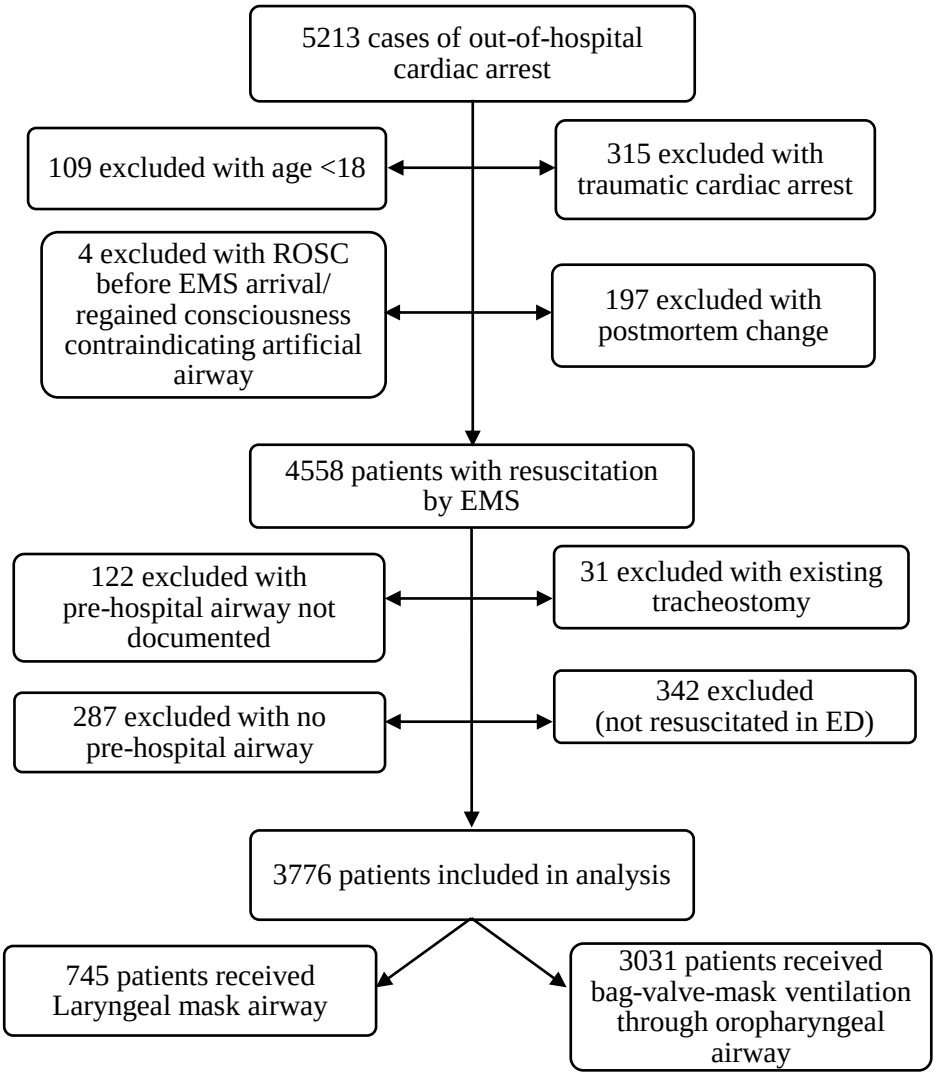


Figure 1. Results of logistic regression models of outcomes with propensity-matched patients.
#Adjustment for confounding variables including age, gender, presumed etiology, initial cardiac rhythm, bystander CPR, witnessed status, defibrillation by bystander and EMS, patient's comorbidity (Charlson comorbidity index), time from EMS call to arrival to patients' side, time from EMS call to hospital arrival

SUPPLEMENTARY MATERIALS

Supplementary Table 3. Baseline characteristics of propensity-matched patients with out-of-hospital cardiac arrest according to initial pre-hospital airway management

Characteristics	All (N=1490)	LMA (N=745)	BVM ventilation (N=745)	p value
Age (mean, SD)	74.6, 15.7	74.2, 16.3	74.9, 15.4	0.896
Gender, male	909 (61%)	454 (60.9%)	455 (61.1%)	0.958
Presumed etiology of cardiac arrest				
Cardiac	515 (34.6%)	256 (34.4%)	259 (34.8%)	0.870
Non-cardiac	204 (13.7%)	113 (15.2%)	91 (12.2%)	0.097
Unknown	771 (51.7%)	376 (50.5%)	395 (53%)	0.325
Initial cardiac rhythm				
VF / VT	166 (11.1%)	78 (10.5%)	88 (11.8%)	0.410
PEA / asystole	1324 (88.9%)	667 (89.5%)	657 (88.2%)	--
Witnessed status				
No witness	893 (59.9%)	454 (60.9%)	439 (58.9%)	0.440
Witnessed by layperson	575 (38.6%)	278 (37.3%)	297 (39.9%)	0.312
Witnessed by EMS	22 (1.5%)	13 (1.7%)	9 (1.2%)	0.390
Bystander CPR	297 (19.9%)	148 (19.9%)	149 (20%)	0.948
Public access defibrillation by bystander	12 (0.8%)	6 (0.8%)	6 (0.8%)	1.000
Defibrillation by EMS	254 (17%)	121 (16.2%)	133 (17.9%)	0.408
Time from EMS call to arrival by patients' side (median, IQR), min	8 (6-11)	8 (6-11)	8 (6-11)	0.289
Time from EMS call to hospital arrival (median, IQR), min	28 (23-32)	28 (24-32)	27 (22-31)	0.129
Charlson Comorbidity Index (median, IQR)	4 (3-7)	4 (3-7)	4 (3-7)	0.159



Supplementary Figure 2. Study participant inclusion flow chart.