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Endotracheal intubation versus supraglottic airway insertion in out-of-hospital cardiac arrest☆

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ABSTRACT

Objective: To simplify airway management and minimize cardiopulmonary resuscitation (CPR) chest compression interruptions, some emergency medical services (EMS) practitioners utilize supraglottic airway (SGA) devices instead of endotracheal intubation (ETI) as the primary airway adjunct in out-of-hospital cardiac arrest (OHCA). We compared the outcomes of patients receiving ETI with those receiving SGA following OHCA.

Methods: We performed a secondary analysis of data from the multicenter Resuscitation Outcomes Consortium (ROC) PRIMED trial. We studied adult non-traumatic OHCA receiving successful SGA insertion (King Laryngeal Tube, Combitube, and Laryngeal Mask Airway) or successful ETI. The primary outcome was survival to hospital discharge with satisfactory functional status (Modified Rankin Scale ≤3). Secondary outcomes included return of spontaneous circulation (ROSC), 24-h survival, major airway or pulmonary complications (pulmonary edema, internal thoracic or abdominal injuries, acute lung injury, sepsis, and pneumonia). Using multivariable logistic regression, we studied the association between out-of-hospital airway management method (ETI vs. SGA) and OHCA outcomes, adjusting for confounders.

Results: Of 10,455 adult OHCA, 8487 (81.2%) received ETI and 1968 (18.8%) received SGA. Survival to hospital discharge with satisfactory functional status was: ETI 4.7%, SGA 3.9%. Compared with successful SGA, successful ETI was associated with increased survival to hospital discharge (adjusted OR 1.40; 95% CI: 1.04, 1.89), ROSC (adjusted OR 1.78; 95% CI: 1.54, 2.04) and 24-h survival (adjusted OR 1.74; 95% CI: 1.49, 2.04). ETI was not associated with secondary airway or pulmonary complications (adjusted OR 0.84; 95% CI: 0.61, 1.16).

Conclusions: In this secondary analysis of data from the multicenter ROC PRIMED trial, ETI was associated with improved outcomes over SGA insertion after OHCA.

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1. Introduction

Airway management is one of the most common and prominent interventions in the treatment of out-of-hospital cardiac arrest (OHCA). In North America, endotracheal intubation (ETI) is the most common form of advanced airway management in OHCA. Paramedics in North America have performed out-of-hospital ETI for over 25 years.[1] Despite the widespread practice of out-of-hospital ETI, numerous studies highlight errors and adverse events associated with the intervention, including unrecognized tube misplacement or dislodgement, multiple intubation attempts, and iatrogenic hypoxia and bradycardia.[2–5] Paramedic ETI efforts may also adversely impact other essential components of resuscitation; for example, a prior study found that paramedic ETI was associated with over 90 s of cardiopulmonary resuscitation (CPR) chest compression interruptions.[6]

An emerging OHCA resuscitation strategy is the use of supraglottic airways (SGAs) instead of ETI.[7,8] SGAs commonly used by North American EMS practitioners include the King Laryngeal Tube (King LT – King Systems, Noblesville, Indiana), Combitube Esophageal/Tracheal Double-Lumen Airway (Combitube – Covidien, Inc., Boulder, Colorado), and the Laryngeal Mask Airway (LMA – LMA North America, San Diego, California). While traditionally used as a rescue airway in the event of failed ETI efforts, SGA insertion has gained favor among EMS practitioners because of its simpler technique and fewer CPR chest compression interruptions than ETI.[9–11] Despite the broadening use of this strategy in North America, there have been few evaluations of outcomes after SGA insertion in OHCA.

The Resuscitation Outcomes Consortium (ROC) Prehospital Resuscitation using an Impedance valve and an Early vs. Delayed analysis (PRIMED) study was one of the largest prospective out-of-hospital controlled trials ever performed, testing the effects of two strategies of ECG analysis and the impedance threshold device (ITD) upon outcomes after OHCA.[12,13] While not dictated by trial protocol, EMS agencies used both ETI and SGA for airway management. The objective of our current study was to compare the outcomes of patients receiving ETI with those receiving SGA after OHCA in the ROC PRIMED trial.

2. Materials and methods

2.1. Study design

This study was a secondary analysis of prospectively collected clinical trial data from the ROC PRIMED study. The ROC PRIMED study was conducted under United States regulations for exception from informed consent for emergency research (21 CFR 50.24), and the Canadian Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans. Additional reviews and approvals were obtained from the US Food and Drug Administration (FDA) and Health Canada, as well as the institutional review boards and research ethics boards in the communities where the research was conducted.

2.2. Setting

The ROC is a North American multicenter clinical trial network designed to conduct out-of-hospital interventional and clinical research in the areas of cardiac arrest and traumatic injury.[14,15] ROC regional coordinating centers participating in the PRIMED trial included communities in: Seattle/King County, WA; San Diego, CA; Milwaukee, WI; Pittsburgh, PA; Portland, OR; Dallas, TX; Birmingham, AL; Toronto, Ontario; Ottawa, Ontario; and British Columbia. In addition, a data and coordinating center was based in Seattle. The ROC network includes over 264 emergency medical services (EMS) agencies, of which 150 participated in the PRIMED trial.[12,13,16]

The interventions of the ROC PRIMED trial included: (1) a comparison of early (immediate) versus delayed (3 min) initial ECG analysis; and (2) a comparison of active ITD with sham device.[12,13] Both studies were stopped for futility at interim analysis, revealing no difference in outcomes between treatment arms. The detailed methods and results of these trials have been published previously.

2.3. Selection of participants – inclusion and exclusion criteria

For this analysis we included adult (≥18 years of age), treated, non-traumatic OHCA enrolled in the ROC PRIMED study and receiving successful out-of-hospital advanced airway attempts, including efforts to perform ETI or SGA insertion. SGA devices used by ROC agencies included King LT, Combitube and LMA. We excluded patients not receiving successful advanced airway insertion efforts. We also excluded patient not requiring any advanced airway insertion efforts. Because they did not use any SGA devices during the study period, we excluded data from Seattle/King County EMS units.

At the time of the PRIMED study, only advanced life support providers performed ETI and/or SGA insertion at the majority of ROC sites. Selection of ETI or SGA was at paramedic discretion and was not dictated by written clinical protocol. The ROC PRIMED studies, as well as other ROC protocols did not dictate the parameters for SGA selection or insertion.

At the Ottawa site, three EMS agencies permitted basic life support personnel to perform King LT insertion. At the San Diego site, while basic life support rescuers were permitted to perform King LT insertion, advanced life support EMS units arrived first for the majority of OHCA.

2.4. Methods of measurement

All ROC sites followed uniform data collection methods consistent with Utstein standards.[15,17] EMS personnel described the details of clinical care on written or electronic patient care reports, including information regarding the airway insertion efforts and outcomes. Each regional center determined hospital outcomes and complications through review of hospital and death records.

2.5. Outcomes and covariates

The primary outcome of this analysis was survival to hospital discharge with satisfactory functional status, defined as a Modified Rankin Scale ≤3.[18] Secondary outcomes were 24-h survival and return of spontaneous circulation (ROSC). In addition, we defined a composite variable for secondary airway and pulmonary complications potentially associated with airway management efforts, including pulmonary edema, internal thoracic or abdominal injuries, acute lung injury, sepsis, and pneumonia.

The key exposure variable was the type of airway (ETI vs. SGA) inserted by EMS personnel. We included only instances of successful ETI or SGA insertion. If a patient received both successful ETI and SGA insertion, we classified the patient as receiving SGA. We excluded cases receiving neither successful ETI nor SGA insertion. Airway insertion success was based upon EMS personnel reports. ROC protocols did not utilize independent confirmation of airway device placement. The data did not contain details regarding the number or sequence of airway attempts.

Other covariates in the analysis included age, sex, bystander or EMS witness of the cardiac arrest event, provision of bystander CPR, initial electrocardiogram (ECG) rhythm, ROC site and PRIMED trial arm. We classified ECG rhythm as shockable (ventricular fibrillation or pulseless ventricular tachycardia, or shock recommended by automated external defibrillator) or non-shockable (pulseless electrical activity or asystole, or no shock recommended when using an automated external defibrillator). ROC PRIMED trial arms included (1) early versus late ECG analysis, and (2) active ITD versus sham device.

2.6. Data analysis

We conducted the primary analysis using multivariable logistic regression, generating separate models for each of the primary (survival to hospital discharge with satisfactory functional status) and secondary outcomes (survival to 24-h, ROSC, and the presence of secondary airway and pulmonary complications). The key exposure in each model was the type of airway (successful ETI versus successful SGA). We adjusted the survival estimates in each model for the confounding effects of age, sex, bystander or EMS witnessed arrest, bystander CPR, initial ECG rhythm, ROC regional coordinating center, and ROC PRIMED trial arm. All 95% confidence intervals were generated using robust standard error estimates.

In a separate sensitivity analysis, we repeated the primary analysis excluding sites with less than 10% SGA insertions (Toronto, Vancouver and Alabama). In the primary analysis if the patient received both successful ETI and successful SGA, we classified the patient as SGA; we repeated the analysis re-classifying these patients as ETI. In addition, the sequence of airway events may have included instances where the patient received ETI or SGA insertion efforts only, initial failed ETI or SGA efforts with subsequent insertion of the alternate device, or unsuccessful attempts with both airway devices. We therefore repeated the analysis using categorical variables representing different ETI/SGA insertion combinations (specific models listed in Supplementary Appendix 1). Because reports of the specific SGA type were incomplete, we chose a priori not to evaluate the associations between individual SGA devices and patient outcomes in the primary analysis. However, we examined this relationship in a sensitivity analysis.

3. Results

During the ROC PRIMED trial, there were 10,455 adult OHCA patients receiving advanced airway management, including 8487 (81.2%) successful ETI and 1968 (18.8%) successful SGA. Among the 1968 SGA the type of device was reported for 1444 cases and included 909 (63.0%) King LT, 296 (20.5%) Combitube, and 239 (16.6%) LMA. SGA insertion attempts varied across the ROC regional sites, ranging from 0% to 64.9% (Supplementary Appendix 2). Of patients receiving advanced airway management, approximately 85% received successful ETI or SGA attempts alone, without any attempts to insert the other airway type (Table 1).

Patients receiving out-of-hospital advanced airway management were older and male (Table 2). Bystander or EMS personnel witnessed more than half of the OHCAs. Approximately one-third received bystander CPR. The initial rhythm was VT/VF in approximately one-fourth of the cases.

Table 1
Advanced airway combinations. ETI = endotracheal intubation; SGA = supraglottic airway.

Advanced airway combination	n	(%)
ETI successful, no SGA attempted	8383	(73.7%)
SGA successful, no ETI attempted	1390	(12.2%)
SGA successful, ETI unsuccessful	442	(3.9%)
ETI successful, SGA unsuccessful	104	(0.9%)
ETI successful, SGA successful	136	(1.2%)
[ETI unsuccessful, no SGA attempted], or [SGA unsuccessful, no ETI attempted], or [ETI unsuccessful, SGA unsuccessful]	923	(8.1%)
Neither ETI nor SGA attempted	2179	–

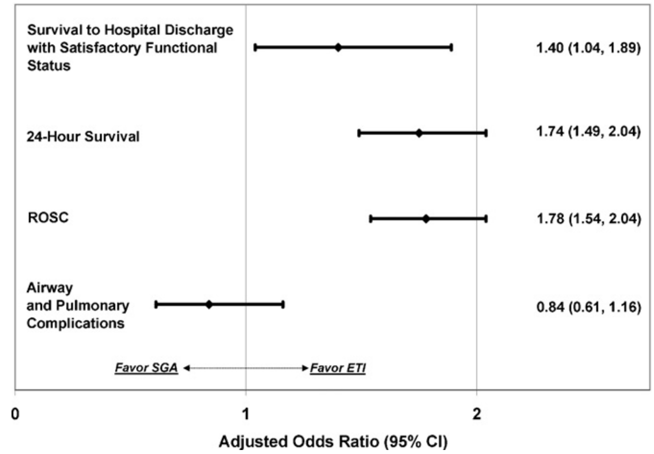

Fig. 1. Adjusted associations of out-of-hospital advanced airway (ETI vs. SGA) with survival to hospital discharge with satisfactory functional status (Modified Rankin Scale ≤3), 24-h survival, return of spontaneous circulation (ROSC) and secondary airway and pulmonary complications. Analysis includes full cohort (n = 10,455) for survival to hospital discharge, 24-h survival, and ROSC, and partial cohort (n = 2564) for secondary airway and pulmonary complications. Full models listed in Appendices 2–4. ETI = endotracheal intubation. SGA = supraglottic airway.

Survival to hospital discharge with satisfactory functional status was 4.7% for ETI and 3.9% for SGA. Compared with successful SGA, successful ETI was associated with increased survival to discharge with satisfactory functional status (OR 1.40; 95% CI: 1.04, 1.89) (Fig. 1 and Supplementary Appendix 3). ETI was also associated with increased odds of 24-h survival (OR 1.74; 95% CI: 1.49, 2.04) or ROSC (OR 1.78; 95% CI: 1.54, 2.04) compared with SGA (Fig. 1 and Supplementary Appendix 4). ETI was not associated with secondary airway or pulmonary complications (OR 0.84; 95% CI: 0.61, 1.16) (Fig. 1 and Supplementary Appendix 5).

In the sensitivity analysis, when excluding ROC sites with less than 10% SGA use (Alabama, Toronto and Vancouver), among the remaining 5182 OHCA, the association of successful ETI insertion with increased survival persisted (Supplementary Appendix 1). In the original analysis, if a patient was described as receiving both successful ETI and successful SGA, we classified the case as successful SGA. When we repeated the analysis with these cases counting as successful ETI, the association between ETI and increased survival persisted.

Multivariable models characterizing various combinations of successful and unsuccessful ETI or SGA insertion revealed similarly consistent results. However, in a model characterizing six different airway combinations, the absence of any successful ETI or SGA insertion (923 of 11,378 patients (8.1%)) was associated with increased survival (OR 1.79; 95% CI: 1.33, 2.40) compared with cases with successful ETI or SGA insertion. A model examining the relationship between ETI and each individual SGA type (King LT, Combitube, LMA) demonstrated no differences in survival, but the type of SGA used was missing for one-third of the 1968 SGA cases.

4. Discussion

In this study we observed that compared with successful SGA insertion, successful ETI was associated with increased survival to hospital discharge with satisfactory functional status after OHCA. Several factors support the validity of this finding. Our data originate from a large multicenter network, representing one of the largest comparative studies of OHCA airway management and reflecting the most current clinical practices in North America. The moderate association between ETI and functionally-intact OHCA

Table 2
Baseline patient characteristics. ETI = endotracheal intubation; SGA = supraglottic airway.

Characteristics	Successful ETI (*n* = 8487)	Successful SGA (*n* = 1968)	Total (*n* = 10,455)
Age (SD)	67.6 (16.6)	64.2 (16.2)	67.0 (16.6)
Sex			
Males (%)	5423 (63.9)	1360 (69.1)	6783 (64.9)
Witnessed arrest			
Not witnessed (%)	4014 (47.3)	947 (48.1)	4961 (47.5)
Bystander witnessed (%)	3621 (42.7)	830 (42.3)	4451 (42.6)
EMS witnessed (%)	852 (10.0)	191 (9.7)	1043 (10.0)
Bystander CPR			
Yes (%)	2997 (35.3)	726 (36.9)	3723 (35.6)
No (%)	5151 (60.7)	1139 (57.9)	6290 (60.2)
Unknown (%)	339 (4.0)	103 (5.2)	442 (4.2)
First rhythm			
VF/VT (%), AED shock	2023 (24.0)	486 (24.7)	2520 (24.1)
PEA, asystole, AED no-shock (%)	6405 (75.5)	1474 (74.9)	7879 (75.4)
Unknown (%)	48 (0.6)	8 (0.4)	56 (0.5)
PRIMED trial arms			
Later vs. Early ECG Analysis			
Late (%)	3931 (46.3)	934 (47.5)	4865 (46.5)
Early (%)	4337 (51.1)	1022 (51.9)	5359 (51.3)
Neither (%)	219 (2.6)	12 (0.6)	231 (2.2)
ITD arm			
Sham (%)	3113 (36.7)	725 (36.8)	3838 (36.7)
ITD (%)	3127 (36.8)	686 (34.9)	3813 (36.5)
Neither (%)	2247 (26.5)	557 (28.3)	2804 (26.8)

survival was complemented by stronger relationships with ROSC and 24-h survival. In a swine OHCA model, Segal et al. observed a 15–50% decrease in carotid blood flow with the use of SGA (King LT, LMA and Combitube) compared with ETI.[19] If there is similar impedance of carotid blood flow in humans, which has not been studied, one would expect similar effects upon neurologic outcome. Small series describe complications associated with Combitube use including aspiration pneumonitis, airway and esophageal injuries, and cranial nerve injury; similar adverse events may be possible with King LT or LMA use in OHCA.[20–22]

While suggesting the superiority of ETI over SGA in OHCA, it is unclear if this interpretation can be applied to all EMS agencies and practitioners nationally. ROC consists of highly trained EMS agencies, and superior ETI and resuscitation skills may have manifested as improved ETI survival over SGA. However, in the United States many EMS agencies have only limited opportunities for ETI training or clinical application, and in these settings SGA insertion may prove more practical and favorable.[17,26–28] Given these and other considerations, it is clear that a prospective randomized clinical trial is the optimal strategy for comparing the relative merits of ETI and SGA in OHCA and accounting for the multiple confounders across a heterogeneous range of EMS providers. In the absence of such data, EMS medical directors and personnel must carefully consider the characteristics of their patient population as well as practitioner experience and training when selecting ETI or SGA as their primary or preferred OHCA airway management strategy.

Select studies have compared SGA with ETI use in OHCA. In an analysis of 5822 OHCAs in Milwaukee, Wisconsin, Cady et al. found no difference in survival to hospital discharge between patients receiving early Combitube insertion by basic level Emergency Medical Technicians and those receiving later ETI by advanced-level paramedics.[23] In the current study, few basic life support EMS personnel performed SGA insertion. More recently, in an analysis of 5377 OHCA in Osaka, Japan, Kajino et al. found no difference in outcomes between patients receiving SGA and those receiving ETI.[24] However, ETI is a relatively new skill for EMS practitioners in Japan. Our analysis originates from North America, where paramedics have performed ETI in clinical practice for over 25 years and may possess greater clinical exposure to and comfort with ETI. A prior study found that OHCA survival is associated with cumulative paramedic ETI experience.[25]

In the secondary sensitivity analysis we observed higher survival among patients not receiving any successful advanced airway placement efforts, a finding that has been echoed by other observational studies (Supplementary Appendix 5, model 2). For example, in an analysis of 1294 OHCA in Los Angeles County, Hanif et al. observed four-fold higher survival among patients receiving bag-valve-mask ventilation than those receiving ETI.[29] In an analysis of 1142 OHCA in Mecklenburg County, North Carolina, Studnek et al. observed higher survival among patients receiving no ETI attempts than those receiving any ETI attempts.[30] Bobrow et al. found superior outcomes with a strategy of early bag-valve-mask or passive ventilation over early ETI.[31] Potential explanations for the superiority of "no airway" include increased interruptions in chest compressions or alterations in ventilatory dynamics from advanced airway insertion, among others.[6] We emphasize that this study included only patients receiving an airway insertion attempt and therefore does not include awake patients or those with intact airway reflexes; one surmises that the latter cases would demonstrate improved survival and be less likely to receive an attempted airway placement compared with overtly comatose patients.

5. Limitations

The interpretation of these results must be tempered by the inherent analytic limitations of the study. The ROC PRIMED clinical trial data were not intended for primary evaluation of airway management techniques. We could not account for pertinent and potentially influential details of airway management such as endotracheal tube or airway misplacement, the number or duration of airway insertion attempts, ventilation rates or tidal volumes, or interruptions in CPR chest compressions associated with airway insertion efforts.[2–6] SGA insertion may have also acted as a surrogate marker for other unidentified or unidentifiable aspects of resuscitation care such as hyperventilation.[32,33] The inability to fully account for confounders is a common and inherent limitation of observational studies.[34] Moreover, in a sensitivity analysis we found no association between survival to discharge and the specific type of SGA, but the SGA type was missing for one-third of the SGA cases, limiting the utility of the observation. Given the many immeasurable confounders, prospective randomized assignment may represent an optimal strategy for comparing OHCA outcomes between ETI and SGA.

SGA insertion practices varied across ROC. Due to the limitations of the data set, we were unable to determine the sequence of advanced airway management; for example, the order of airway device insertion, or whether airway insertion occurred before or after return of pulses. Due to the uncertain accuracy of reported times, we did not compare times to airway placement. While the type of airway device may represent a surrogate marker for the knowledge, capabilities, protocols or practice styles of individual or groups of EMS practitioners, the current data set was unable to separate these potential confounding factors.

While we examined a limited number of pulmonary adverse events in this series, these data were intended to evaluate the parent trial intervention (the ITD), not different airway management devices. Formal evaluations of SGA safety must include the systematic identification of other adverse events, including downstream in-hospital adverse events such as airway, pharyngeal or gastroesophgeal injury, acute lung injury or aspiration pneumonitis.

6. Conclusions

In this secondary analysis of data from the multicenter ROC PRIMED trial, ETI was associated with improved outcomes over SGA insertion after OHCA. EMS medical directors must consider patient characteristics, device efficacy and practitioner skill and training when selecting OHCA airway management strategies.

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Conflict of interest statement

None declared.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.resuscitation.2012.05.018

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