Airway management in cardiopulmonary resuscitation

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Airway management in cardiopulmonary resuscitation

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Purpose of review
The optimal method for airway management during cardiac arrest is unknown. This review summarizes recent evidence comparing the use of basic and advanced airway interventions [insertion of supraglottic airway (SGA) devices and tracheal intubation], including the role of capnography during cardiac arrest.

Recent findings
A large observational study [649 359 out-of-hospital cardiac arrests (OHCAs)] has shown that the risk-adjusted odds of neurologically favourable survival were higher for those treated with bag-mask ventilation compared with SGA insertion or tracheal intubation. Two recent, large observational studies suggest that tracheal intubation for OHCA may be superior to SGA use. These observational studies share an important weakness: they rely on statistical risk-adjustment to account for other factors that may influence outcome, and hidden confounders may account for the differences in outcome associated with each of the airway management strategies.

Summary
Most of the evidence about airway management during cardiac arrest comes from observational studies. The best airway option is likely to be different for different rescuers, and at different time points of the resuscitation process. Properly designed, prospective, randomized trials are needed to help determine the optimal airway strategy. In our view, there is currently sufficient clinical equipoise to support such trials.

Keywords
airway management, bag-mask ventilation, cardiopulmonary resuscitation, supraglottic airway, tracheal intubation

INTRODUCTION

Airway management during cardiopulmonary resuscitation (CPR) is at a crossroads. The conventional wisdom that airway opening and ventilation is essential during CPR, and that advanced airway techniques are the 'gold standard' is no longer universally supported. It still holds true, however, that at some point in the resuscitation process an open airway, adequate ventilation and oxygenation, will be essential. Without this it may be impossible to restore and/or maintain a perfusing cardiac rhythm. There will also be a need to protect the lungs from injury caused by aspiration of gastric contents. The best airway approach may be different for out-of-hospital cardiac arrest (OHCA) and in-hospital cardiac arrest (IHCA). In this review we will discuss recent studies of airway management for cardiac arrest and attempt to provide some clarity on the current state-of-play.

CURRENT GUIDELINES

According to current guidelines for an adult OHCA patient [1,2]:

(1) An untrained lay rescuer gives compression-only CPR guided by an emergency medical service (EMS) telephone-dispatcher.
(2) A trained lay rescuer can give mouth-to-mouth ventilations if willing and able to do so.

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KEY POINTS

- The optimal method for airway management during cardiac arrest is unknown.
- The best airway option is likely to be different for different rescuers, and at different time points of the resuscitation process.
- Patients can have more than one type of airway intervention during cardiopulmonary resuscitation.
- Properly designed, prospective, randomized trials are needed to help determine the optimal airway strategy during cardiac arrest.
- There is currently sufficient clinical equipoise to support trials comparing basic and advanced airway interventions during cardiopulmonary resuscitation.

(3) On arrival EMS rescuers can use a variety of airway and ventilation techniques according to local protocols. Options include an initial period of compression-only CPR with high-flow oxygen by face-mask [3], bag-mask ventilation, insertion of one of the many types of supraglottic airway (SGA) device, or tracheal intubation.

In practice, in many cardiac arrests more than one airway technique will be used, both during CPR and after return of a spontaneous circulation (ROSC). The choice of airway and ventilation technique depends on the skills and experience of the rescuer.

IS INITIAL AIRWAY MANAGEMENT AND VENTILATION REQUIRED DURING CARDIOPULMONARY RESUSCITATION?

A meta-analysis of pooled data from three randomized trials of EMS dispatcher CPR instructions showed that chest compression-only CPR was associated with improved survival compared with standard CPR [14 (211/1500) versus 12% (178/1531); risk ratio 1.22, 95% confidence interval (CI) 1.01–1.46] [4,5]. A long-term follow-up analysis of two of these studies has shown that the mortality benefit of dispatcher-assisted chest compression-only CPR is sustained for up to 5 years [6▪]. Possible reasons for benefit of dispatcher-assisted chest compression-only CPR over standard CPR include:

(1) Arterial blood can remain saturated with oxygen for several minutes in primary cardiac arrest [7,8].
(2) Rescuers are unwilling or unable to provide effective mouth-to-mouth ventilations [9].
(3) Implementation of a chest compression-only CPR programme can increase lay-bystander CPR rates [10].
(4) Prolonged pauses in chest compressions, even when effective ventilations are given, can reduce the chances of survival [11,12].
(5) In the presence of an open airway, chest compressions generate airflow in and out of the lungs, although the measured tidal volumes are small and generally no more than the anatomical dead space [13].

Some EMS system protocols for adult primary cardiac arrest include airway opening and high-flow face-mask oxygen, and passive ventilation from chest compressions for the first 6 min of CPR. Improved outcomes have been reported with this 'minimally interrupted' CPR approach although further study is needed [14]. A retrospective analysis of adult OHCA patients reported improved neurologically intact survival after witnessed ventricular fibrillation/ventricular tachycardia (VF/VT) OHCA with passive ventilation compared with bag-mask ventilation. Survival was similar for unwitnessed VF/VT and nonshockable rhythms. Observational data from large registries in Japan, however, suggest that ventilation is necessary during CPR in children, after cardiac arrest with a primary respiratory cause, and during a prolonged cardiac arrest [15,16].

ARE BASIC AIRWAY TECHNIQUES BEST DURING CARDIOPULMONARY RESUSCITATION?

Initial bag-mask ventilation with a self-inflating bag has been the mainstay of professional rescuer airway management for cardiac arrest. Bag-mask ventilation, usually with an airway adjunct (oropharyngeal or naso-pharyngeal airway), is commonly used until advanced airway techniques such as SGA insertion or tracheal intubation are feasible. Bag-mask ventilation requires interruption of chest compression, can lead to gastric insufflation, and does not protect the lungs from aspiration of gastric contents. Several recent studies, however, suggest bag-mask use remains the best option for cardiac arrest compared with advanced techniques [17▪▪,18▪,19–21].

The most compelling evidence supporting bag-mask use comes from a prospective, nationwide, Japanese registry of 649 654 consecutive adult OHCA patients which showed that bag-mask ventilation is associated with improved ROSC, one-month survival and neurological outcome when compared to both tracheal intubation and SGA use [17▪▪]. All included patients were transported to hospital and arrests occurred between January 2005 and December 2010. Bag-mask ventilation was used in 367 837 (57%) patients, SGAs [laryngeal mask airway (LMA), laryngeal tube or 'oesophageal-tracheal twin lumen' airway] in 281 522 (43%), and tracheal intubation in 41 972 (6%). Use of an advanced airway (SGA or tracheal intubation) was associated with worse neurological outcome in comparison with use of a bag-mask [1.1 versus 2.9%; odds ratio (OR), 0.38; 95% CI 0.36–0.39]. Multivariable logistic regression, adjusting for known factors that influence outcome (age, sex, arrest aetiology, first documented rhythm, witnessed, bystander CPR, public access automated external defibrillator, adrenaline use, time intervals), gave an adjusted odds ratio for favourable neurological outcome for advanced airway of 0.38 (95% CI 0.37–0.40). There were worsened outcomes compared with bag-mask ventilation with both tracheal intubation (adjusted OR, 0.41; 95% CI 0.37–0.45) and SGAs (adjusted OR, 0.38; 95% CI 0.36–0.40). A propensity score matched cohort of 357 228 patients also supported these observations and showed similarly worse adjusted odds of neurologically favourable survival with both tracheal intubation and SGA use.

Smaller studies also support these Japanese findings. A retrospective single US centre review of 1294 nontraumatic OHCAs between 1994 and 2008 found tracheal intubation by paramedics was associated with worse survival to discharge (adjusted OR bag-mask versus tracheal intubation 4.5, 95% CI 2.3–8.9) [19]. This negative association was also seen in another US single EMS study in which basic airway management was associated with an adjusted OR of 2.33 (95% CI 1.63–3.33) compared with successful intubation for survival to discharge [20]. A Korean OHCA database used propensity matching to compare outcomes for tracheal intubation, bag-mask ventilation or LMA insertion [18▪,22]. Adjusted survival to admission and discharge were similar for tracheal intubation and bag-mask: OR 1.32 (95% CI 0.81–2.16) and 1.44 (0.66–3.15). Adjusted survival to admission was similar for LMA and bag-mask: OR 0.72 (0.50–1.02). However, survival to discharge was significantly lower for LMA than bag-mask: OR 0.45 (0.25–0.82). Nagao observed no difference in favourable neurological outcome at hospital discharge for advanced airway ($n = 199$, tracheal tube 10, LMA 147, Combitube 42 patients) and bag-mask ventilation ($n = 156$) for OHCA patients. Finally, a small IHCA study ($n = 105$) also reported improved neurological survival to discharge with bag-mask ventilation with airway adjuncts (oro-pharyngeal or naso-pharyngeal airways) compared with tracheal intubation [23].

The differences in outcome when comparing basic and advanced airway techniques may be attributed to the technique, or unreported factors known to adversely impact cardiac arrest survival including the timing of airway interventions, skills of the rescuers, the quality of CPR and the no-flow fraction [11,12,24]. An analysis of CPR-quality data from OHCAs showed a median of 2 [interquartile range (IQR) 1–3; range 1–9] CPR interruptions for tracheal intubation by paramedics, with almost a third exceeding 1 min and a quarter exceeding 3 min [25].

DO ADVANCED AIRWAYS STILL HAVE A ROLE IN THE TREATMENT OF CARDIAC ARREST PATIENTS?

The data supporting a basic airway approach do not mean that we should cease using advanced airways in cardiac arrest patients. Although some cardiac arrest patients achieve ROSC and regain consciousness without the need for an advanced airway, others will need an advanced airway at some stage of the resuscitation process, be it during CPR at the scene, to facilitate transport, or as part of post-resuscitation care after ROSC in those who remain comatose. The choice of advanced airway device between tracheal intubation and SGA, therefore, remains an important one. Issues to consider when making comparisons include:

(1) Not all SGAs are the same and insertion success rates vary [26,27]. SGAs are often lumped together in analyses.
(2) Most studies do not use newer (second generation) SGAs such as the LMA Supreme or i-gel [28▪].
(3) SGAs are often used as a rescue device in the 'cannot intubate cannot ventilate' scenario.

Supraglottic airways versus tracheal intubation?

We have discussed the pros and cons of tracheal intubation and SGAs in a previous review [29]. Two recent observational studies suggest that tracheal intubation for OHCA may be superior to SGA use [30▪▪,31▪]. The North American Resuscitation Outcomes Consortium (ROC) PRIMED study showed no difference in outcomes when comparing the use of an active impedance threshold device (ITD) with a sham ITD in OHCA patients during standard CPR [32]. A secondary analysis of this study comparing tracheal intubation ($n = 8487$) with SGAs (laryngeal tube, Combitube, or LMA; $n = 1968$) showed that successful tracheal intubation was associated with increased survival to hospital discharge with Modified Rankin Scale score 3 or less (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) when compared with successful SGA insertion [30▪▪]. In a Japanese OHCA study, tracheal intubation (16 054 patients, 12%) was compared with the LMA (34 125, 25%) and the oesophageal obturator airway (88 069, 63%) over a 3-year period (2005–2007) [31▪]. Adjusted ORs for favourable 1-month survival were lower for LMA (0.77, 95% CI 0.64–0.94) and oesophageal obturator use (0.81, 95% CI 0.68–0.96) in comparison with tracheal intubation. These two observational studies have the same weaknesses that are associated with the studies that have compared basic and advanced airway use: even though the data are risk-adjusted in attempt to account for all potential confounders, there is still a strong possibility that hidden factors account for the findings.

Insertion of a SGA (LTS-D, LMA Flexible, Combitube) during CPR in a swine model caused compression of the internal and external carotid arteries and a decrease in carotid artery blood flow when compared with tracheal intubation [33▪]. The effect of SGAs on carotid blood flow has not been studied in human cardiac arrest but an imaging study of an anesthetized patient showed that the AirQ SGA did not cause carotid artery compression [34].

Skills for tracheal intubation are not available in all settings. The use of SGAs as an 'easier alternative' has made them popular for both IHCA and OHCA use [35–37]. For example, a single UK hospital reported an 82% first attempt and 99% overall success rate for i-gel use during CPR [35]. Placement success (ventilation to chest rise, no gastric sounds, bilateral lung sounds, and when applicable, quantitative end-tidal CO_2 readings) by paramedics was similar for the LTS-D and tracheal intubation (tracheal intubation 80.2 versus LTS-D 80.5%; $P = 0.97$) [38]. In another OHCA study, first attempt LT-D success rates by basic life support responders were higher than tracheal intubation by paramedics (87.8 versus 57.6%, OR 5.3; 95% CI 2.9–9.5) [39].

Problems with tracheal intubation

Tracheal intubation in emergency scenarios such as cardiac arrest is challenging and associated with significant complications [40,41]. The incidence of in-hospital difficult intubation (Cormack and Lehane grade at least 3, or at least three intubation attempts) was 10.3% in 3423 emergency intubations by physicians (respiratory distress in 52%, cardiac arrest 45%, airway protection 2%, other 1%) [42]. A similar incidence (13%) of difficult intubation, and predisposing factors (lack of space, short neck, obesity, face/neck injuries) has been reported by a physician-staffed EMS system [43]. This is about twice the incidence of unexpected difficult intubation for general anaesthesia 5.8% (95% CI 4.5–7.5%) [44]. A prospective database of tracheal intubation in 10 Japanese emergency departments (1486 intubations, 502 for cardiac arrest) reported a first attempt success rate in the range of 40–83%, and success with three or less attempts in 74–100% of departments [45]. The overall adverse event rate was 11% and unrecognized oesophageal intubation was 3.9%. A meta-analysis of observational studies of airway management in OHCA estimated a success rate of 91.2% (95% CI 88.8–93.1) for tracheal intubation [26]. This study also observed a decline in nonphysician tracheal intubation success of 0.49% per year. This may reflect better reporting and recording of data, or an actual worsening of skills. More recent data from the US National Emergency Medical Services Information System reported a tracheal intubation success rate of 78% (3494/4482) for OHCA [46]. Lyon *et al.* [41] reported UK data from a UK 4-year retrospective review of 794 OHCAs and 628 intubation attempts. Prehospital intubation was successful in three or less attempts in 573 (91.2%), and 55 had significant complications (multiple failed attempts in 32, unrecognized oesophageal intubation in 15, tube displacement during transport in three, endobronchial intubation in three, tube cuff above cords in two).

Experience is important for tracheal intubation

Tracheal intubation requires extensive training [47▪] and regular practice to avoid skill decay. Among 21 753 OHCA patients treated by EMS rescuers in Pennsylvania, adjusted odds of survival was higher for patients intubated by rescuers with 'very high' tracheal intubation experience (>50 cumulative tracheal intubations) compared with those of low tracheal intubation experience (1–10 cumulative tracheal intubations): adjusted OR 1.48; 95% CI 1.15–1.89 [48]. In an EMS study from Germany, increasing experience of physicians (median 304 intubations per year in all settings versus 18 intubations per year) was associated with a lower incidence of prehospital difficult tracheal intubation (8.9 versus 17.7%, $P < 0.05$) [49▪]. This intubation experience is considerably greater than numbers reported for many EMS systems where some individuals will only attempt one intubation per year [50–52].

ROLE OF CAPNOGRAPHY

Waveform capnography is recommended for identification of correct tracheal tube placement during CPR [2,53]. Cardiopulmonary resuscitation will produce enough pulmonary blood flow to generate an end-tidal CO_2 trace, unless cardiac arrest has been prolonged (>30 min). A UK national airway audit (NAP4) showed that capnography was not routinely used during CPR, and when it was used a flat capnograph trace was misinterpreted as a result of cardiac arrest, rather than oesophageal intubation [54]. In addition to confirmation of tracheal tube placement, waveform capnography may also have a role in assessing the quality of chest compressions during CPR, and provides early indication of ROSC [55,56■■]. Heradstveit *et al.* [56■■] described capnography data from 575 OHCA patients. They observed that patients with ROSC tended to have a high end-tidal carbon dioxide ($ETCO_2$) value. Confounders such as cause of arrest, initial rhythm, and bystander CPR affect $ETCO_2$ values, and therefore limit the prognostic role of waveform capnography during CPR [57]. The value and role of capnography during CPR using bag-mask ventilation or a SGA requires further study.

RANDOMIZED STUDIES OF AIRWAY MANAGEMENT DURING CARDIOPULMONARY RESUSCITATION ARE NEEDED

The current evidence to support airway management during CPR is based on observational studies with a high potential risk of bias. In a recent editorial, Wang and Yealy [24] correctly state 'these observations collectively suggest that scientific equipoise exists among the various airway management options'. There is currently a dearth of ongoing studies looking at airway interventions in cardiac arrest (Table 1). Much of the evidence for airway interventions during CPR is extrapolated from manikin studies or from patients undergoing general anaesthesia. The value of manikin studies, in particular, has been questioned, largely because results depend on the fidelity of the manikin and this is rarely good enough to enable reliable extrapolation to humans [58]. Designing a study that tests specific airway interventions is challenging because the correct approach will vary with rescuer training and experience, and the time point in the cardiac arrest. Different rescuer groups may also not have equipoise as tracheal intubation is still seen by many as the 'gold standard' of airway management. The availability of new airway devices such as video laryngoscopes and modifications of existing devices, also makes decisions about precisely which airway devices to compare difficult. The UK Difficult Airway Society has produced guidance on evaluation of new airway devices before clinical use [59]. The available observational data suggest future study designs should include a group that uses basic airway interventions as the initial airway strategy. The use of waveform capnography to confirm tracheal tube placement should be a requirement of future studies. The REVIVE-Airways study is a single-EMS feasibility study comparing standard treatment according to rescuer preference, and two SGAs (i-gel and LMA Supreme) [28■]. The findings of this study will hopefully provide useful insights for those designing large multicentre studies.

Table 1. Ongoing registered trials of airway management for adult cardiac arrest

Registration number	Title	Study type	Primary outcome
NCT01295749	Effects of laryngeal tube ventilation on no-flow time during out-of-hospital cardiac arrest	Randomized intervention trial	Comparison of no flow time between Group A (ventilation by bag valve mask and interrupted chest compression) and Group B: (ventilation by laryngeal tube and continuous chest compression). Outcome measure: no-flow time during resuscitation by trained paramedical staff in out-of-hospital cardiac arrest patients
ISRCTN18528625	Randomized comparison of the effectiveness of the Laryngeal Mask Airway Supreme, i-gel and current practice in the initial airway management of prehospital cardiac arrest: a feasibility study (REVIVE-Airways)	Randomized interventional trial	Assess if it is possible to conduct a full-scale study

(Data from http://www.controlled-trials.com search on 31 January 2013).

Table 2. Airway and ventilation techniques for cardiac arrest

Technique	Compression-only CPR	Mouth-to-mouth	Bag-mask	Supraglottic airway	Tracheal intubation
Difficulty of technique	Easiest	+	+++	++	+++++
Pause in compressions needed for ventilations	None	++++	++	+	None
Gastric inflation	No	++	+++	+	No
Risk of gastric aspiration	+++	++++	++++	++	+
Level of training and experience required	Untrained lay persons usually with EMS telephone dispatcher instructions	+	+++	++	+++++

EMS, emergency medical service.

CONCLUSION

There are a variety of approaches to airway management for cardiac arrest (Table 2). Most of the available evidence comes from observational studies. There is no good evidence to support any advanced airway technique over basic techniques such as bag-mask ventilation. The best airway option is likely to be different for different rescuers, and at different time points of the resuscitation process. The only reliable way to determine the optimal airway management strategy during cardiac arrest is to undertake properly designed, prospective, randomized trials.

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Conflicts of interest

J.S. is a steering group member for the REVIVE airways study, ALS task force co-chair for ILCOR, and vice chair Resuscitation Council (UK) (all unpaid). He receives an honorarium as editor of the journal Resuscitation.

J.P.N. is an investigator for the REVIVE airways study (unpaid). He receives an honorarium as Editor-in-chief of the journal Resuscitation.

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