Emergency airway management by non-anaesthesia house officers—a comparison of three strategies

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Abstract

Objectives—The purpose of this study was to determine effects of different airway devices and tidal volumes on lung ventilation and gastric inflation in an unprotected airway.

Methods—Thirteen one non-anaesthesia house officers volunteered for the study, and ventilated a bench model simulating an unintubated respiratory arrest patient with bag-valve-facemask, laryngeal mask airway, and combitube using paediatric and adult self inflating bags.

Results—The paediatric versus adult self inflating bag resulted with the laryngeal mask airway and combitube in significantly (p<0.001) lower mean (SEM) lung tidal volumes (376 (30) v 653 (47) ml, and 368 (28) v 727 (53) ml, respectively). Gastric inflation was zero with the combitube; and 0 (0) v 8 (3) ml with the laryngeal mask airway with low versus large tidal volumes. The paediatric versus adult self inflating bag with the bag-valve-facemask resulted in comparable lung tidal volumes (245 (19) v 271 (33) ml; p=NS); but significantly (p<0.001) lower gastric tidal volume (149 (11) v 272 (24) ml).

Conclusions—The paediatric self inflating bag may be an option to reduce the risk of gastric inflation when using the laryngeal mask airway, and especially, the bag-valve-facemask. Both the laryngeal mask airway and combitube proved to be valid alternatives for the bag-valve-facemask in this experimental model.

Key words: bag-valve-mask; laryngeal mask airway; combitube; tidal volume; gastric regurgitation

Inhospital cardiopulmonary resuscitation (CPR) response teams may consist of a non-anaesthesiologist because of shortage in experienced anaesthesiologists, or intensive care unit physicians. Also, it is quite common that hospital buildings are spread over a large area or in many different floors, or both. As such, many hospitals may not be able to dispatch experienced anaesthesiologists to remote locations for prolonged periods of time to administer CPR, as this would render a critical care unit or even operation room unattended. Thus, the physician in charge of an inhospital CPR attempt may be one of the clinically lesser experienced physicians, but has to carry full responsibility with regard to pharmacological interventions, and especially, airway management. Accordingly, if an airway device can be identified that is easiest to handle for this target group, CPR efforts may benefit.

For rescuers who do not have adequate skills in tracheal intubation, the most common means of providing emergency ventilatory support in non-intubated patients during CPR is the bag-valve-facemask system.1 As bag-valve-facemask ventilation has a number of disadvantages, such as leakage around the facemask, and gastric inflation,2–6 the laryngeal mask airway and the combitube may be an alternative to bag-valve-mask ventilation.7–14

Hence, the purpose of this study was to assess lung ventilation and gastric inflation when non-anaesthesia house officers perform ventilation with the bag-valve-facemask system, the laryngeal mask airway, and the combitube in a bench model. Furthermore, it was investigated whether smaller tidal volumes, as recommended by the European Resuscitation Council,15 but not by the American Heart Association, at the time of this investigation,16 is beneficial in order to reduce the risk of gastric inflation as suggested by some previous bench models simulating a cardiac arrest patient.17–19

Methods

Experimental model

A bench model simulating an unintubated cardiac arrest patient was designed with a new intubation manikin head (Bill I, VBM Medizintechnik, Sulz, Germany), and a lung simulator (LS 800, Dräger, Lübeck, Germany). Lung compliance (50 ml/cm H2O),20–22 airway resistance (16 cm H2O/l second),23 and lower oesophageal sphincter pressure (6 cm H2O)24 were adjusted to simulate respiratory mechanics of a cardiac arrest patient. Respiratory parameters were recorded using the AS 3 compact monitor (Datex Ohmeda, Helsinki, Finland). Subsequently, this setup was connected to a paediatric pneumotachometer to record oesophageal peak pressure, and gastric inflation (fig 1).

Experimental protocol

Thirty one non-anaesthesia house officers with no previous experience in emergency airway
management volunteered in this study; and signed written informed consent before participation.

All volunteers were instructed with theoretical and hands on teaching to appropriately use the facemask size 4 (Ambu, Hanau, Germany), a size 4 laryngeal mask airway (LMA International Services Ltd, UK), and a size 41 combitube (Tyco Sheridan, Argyle, NY) by the instructor before the study. Positioning of the combitube was confirmed using the tube check (oesophageal detector; Ambu, Hanau, Germany). For ventilation, we chose an adult and paediatric self inflating bag (maximum volume, 1500 and 700 ml, respectively; Dräger, Lübeck, Germany). The participants then used each ventilatory device with both self inflating bags in a randomised sequence for a two minute ventilation attempt of the model simulating a cardiac arrest patient.

The time to attain the end expiratory tidal lung volume exceeding 200 ml was recorded. If this volume could not be achieved within 180 seconds, it was deemed that the ventilation attempt had failed. Peak airway pressures at the pharynx level and in the oesophagus were recorded, as well as lung and gastric tidal volumes during each attempt. Each volunteer was graded by the instructor from 1 (excellent) to 4 (bad) in regards of airway insertion success, quality of the seal, and visible adequacy of ventilation. Accordingly, a subjective grading by the volunteer (1–4) about the different devices in conjunction with the two sizes of self inflating bags was made after the trial.

**STATISTICAL METHODS**

The Mann-Whitney U test was chosen for the comparison of the two self inflating bags. The Friedman test was performed to determine significant differences within the ventilatory devices. Comparison by pairs of the ventilatory devices was performed with the Wilcoxon test. Comparison in regards of stomach inflation was assessed with Fisher’s exact test; α was set at 0.05.

**Results**

Thirty one non-anaesthesia house officers (15 male, 16 female, age 29–39; specialty: two neurologists, two obstetricians/gynaecologists, two psychiatrists, six surgeons, 14 internists, three paediatricians, two ear, nose and throat surgeons, respectively) volunteered. Two participants needed >180 seconds to deliver a lung tidal volume of >200 ml with the bag-valve-facemask, three in the laryngeal mask airway group, and two in the combitube group (table 1). The time to deliver the first adequate tidal volume ranged from 4–107 seconds (median, 14 seconds) for the bag-valve-facemask, 17–129 seconds (median, 29 seconds) for the laryngeal mask airway, and 32–180 seconds (median, 61 seconds) for the combitube, respectively (p<0.01 bag-valve-facemask vs laryngeal mask airway, combitube, respectively; p<0.01 laryngeal mask airway vs combitube).

When the participants used the paediatric self inflating bag, tidal lung volumes with both laryngeal mask airway and combitube were significantly (p<0.001) lower when compared with the adult self inflating bag. Tidal lung volume showed no significant difference between both bags in the bag-valve-facemask group. In contrast, the use of the paediatric compared with adult self inflating bag resulted in a significantly (p<0.001) lower oesophageal tidal volume in the bag-valve-facemask group (table 2).

Use of the combitube resulted in a significantly (p<0.001) higher tidal lung volume, and peak airway pressure with the adult self inflating bag compared with the bag-valve-facemask; furthermore, the combitube was the only ventilatory device without gastric

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**Table 1: Number of ventilation failures and number of volunteers inflating the stomach with each airway device**

<table>
<thead>
<tr>
<th>Airway devices</th>
<th>Bag-valve-facemask</th>
<th>Laryngeal mask airway</th>
<th>Combitube</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilation failures</td>
<td>2/31</td>
<td>3/31</td>
<td>2/31</td>
</tr>
<tr>
<td>Stomach inflation</td>
<td>29/29*</td>
<td>7/28†</td>
<td>0/29</td>
</tr>
</tbody>
</table>

Data are given in absolute numbers. *p<0.01 versus laryngeal mask airway and combitube. †p<0.01 versus combitube.
Data are given as mean (SEM). Vₜ = tidal volume, Pₐw = airway pressure, Poesoph = oesophageal pressure. ‡*p<0.01 versus laryngeal mask airway. †p<0.01 adult bag versus paediatric self inflating bag, *p<0.01 versus bag-valve-facemask for all ventilatory devices and both self inflating bags.

<table>
<thead>
<tr>
<th>Device</th>
<th>Paediatric bag</th>
<th>Adult bag</th>
<th>Paediatric bag</th>
<th>Adult bag</th>
<th>Paediatric bag</th>
<th>Adult bag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Pₐw (cm H₂O)</td>
<td>12 (1)</td>
<td>14 (1)</td>
<td>16 (1)*</td>
<td>20 (1)*</td>
<td>24 (1)*</td>
<td>24 (1)*</td>
</tr>
<tr>
<td>Peak Poesoph (cm H₂O)</td>
<td>11 (1)</td>
<td>12 (1)</td>
<td>3 (0.5)*</td>
<td>3 (0.5)*</td>
<td>635 (47)*</td>
<td>653 (47)*</td>
</tr>
<tr>
<td>Vₜ Lang (ml)</td>
<td>245 (19)</td>
<td>271 (33)</td>
<td>368 (28)*</td>
<td>727 (53)*</td>
<td>376 (30)*</td>
<td>653 (47)*</td>
</tr>
<tr>
<td>Vₜ Oesoph (ml)</td>
<td>149 (11)</td>
<td>272 (24)*</td>
<td>0 (0)*</td>
<td>8 (3)*</td>
<td>0*</td>
<td>0*</td>
</tr>
</tbody>
</table>

Both laryngeal mask airway and combitube were graded significantly (p<0.001) better than the bag-valve-facemask by the participants in their subjective assessment. In terms of success of airway insertion, quality of seal, and adequacy of ventilation, the instructors ranked the laryngeal mask airway and combitube significantly (p<0.01) better than the bag-valve-facemask as well.

**Discussion**

When paramedics in the Houston, Texas, Emergency Medical Service were trained to administer advanced airway management, ventilation associated complications were more related to training efforts than to the airway devices themselves. When extrapolating this experience to non-anaesthesia house officers in order to provide in-hospital advanced cardiac life support, two pragmatic solutions may be possible: (1) extensive, continuous training; and (2) standing orders favouring an airway device that is simple to handle with little training. While paramedics, emergency physicians, and anaesthesiologists perform basic and advanced cardiac life support on a daily basis, non-anaesthesia house officers may spend a large portion of their residency in rotations without the need to handle respiratory or cardiac emergencies, or both, on a daily basis, or possibly, even never in their training. Also, training and maintaining advanced airway skills in all or at least some residents may be a cost issue, especially as money allocated to healthcare is decreasing.

The dilemma of tracheal intubation is that at least in some cases, adverse effects such as an anterior larynx, presence of vomitus in the pharynx, obesity, a short neck, or simply no adequate training may render intubation conditions extremely difficult. While an anaesthesiologist may be able to master all of these problems because of experience of several hundred or even thousands of intubations, non-anaesthesia house officers may fail to secure the airway because of lack of education or continuous training, or both. This has fundamental practical implication. While services such as helicopter emergency medical service programmes or accident and emergency departments are always staffed with persons with an extensive and continuous background in emergency airway management, inhospital CPR response teams often consist of house officers or even nurses while some small hospitals may not even have a CPR response team at all. For example, our volunteers reflect a wide variety of physicians from neurology, obstetrics/gynaecology, psychiatry, surgery, internal medicine, pediatrics, ear, nose and throat with no or very limited experience in emergency airway management; who participated in a class to study management of emergency patients with diseases such as myocardial infarction, stroke, respiratory, and cardiac arrest. Although none of the house officers in our group was routinely assigned to inhospital cardiac arrest teams as part of their clinical training, they had to carry full responsibility in regards of pharmacological interventions, and especially, emergency airway management during CPR. Accordingly, the chance that a non-anaesthesia physician provides emergency airway management is actually quite possible. These physicians may be a psychiatrist managing a patient with an overdose, an ENT surgeon seeing a patient with severe pharyngeal haemorrhage, an eye physician confronted with an anaphylactic shock, or an orthopaedic surgeon trying to rescue a patient with pulmonary embolus. In that case, if the response time of the cardiac arrest team is anywhere between two and five minutes, initial airway management in that time will have decided whether the stomach is inflated, or if the patient remains hypoxic or hypercarbic, or both, or if the patient is adequately ventilated and oxygenated.

This study suggests that use of the laryngeal mask airway and the combitube was beneficial. The bag-valve-facemask resulted in the least gastric inflation, and insufficient pulmonary tidal volumes. However, small instead of large tidal volumes had a relative advantage, especially when using a bag-valve-facemask. Although the combitube was the only device that safely prevented gastric inflation in our bench model, the associated training commitment with this device possibly may not be guaranteed in non-anaesthesia house officers. Also, the time required for insertion of the combitube was significantly longer than with both bag-valve-facemask and laryngeal mask airway resulting in approximately 30 seconds longer potential hypoxaemia and hypercarbia. Therefore, for physicians with little experience in airway management, our data may tip the scales towards using the laryngeal mask airway because ease of handling, and speed of insertion.

One approach to achieve proper ventilation may be the choice of the best ventilatory device; another strategy may be a smaller tidal volume, as recently recommended by the European Resuscitation Council in order to minimise gastric inflation during ventilation of an unprotected airway. Thus, the best combination of the right “hardware”, and the right tidal volume may contribute to sufficient oxygenation and ventilation, and may avoid...
gastric inflation. For example, our bag-valve-facemask group clearly demonstrates that small tidal volumes almost cut gastric inflation in half, while maintaining lung volumes. However, when using either ventilation bag with the bag-valve-facemask, only about 50% to 60% of the recommended lung tidal volumes were achieved. Both the laryngeal mask airway and especially, the combitube were the superiour devices in regards of minimizing or even avoiding gastric inflation with either ventilation bag.12 31 However, it has to be pointed out that when using small tidal volumes with either ventilatory device in our bench model, lung volumes between about 250 ml to 380 ml were achieved, which is significantly less than the 500 ml recommended by the European Resuscitation Council.3 This is especially important as almost approximately 50% oxygen has to be used when administering tidal lung volumes of < 400 ml, or larger tidal volumes of > 600 ml when room air has to be used to maintain both sufficient oxygenation and ventilation.32 34 The new international guidelines of both the ERC and AHA now recommend small tidal volumes of about 50 ml with an FIO2 of >0.4 when ventilating an unprotected airway. These recommendations are based, in part, on our experience, and further indicate the clinical significance of our observation.35 36 Some limitations of our study should be noted. Firstly, our model is a tough challenge with a lower oesophageal sphincter pressure of 6 cm H2O, reflecting a cardiac arrest patient.47 48 Thus, the performance of our volunteers most probably would have been better when a respiratory arrest patient without cardiac arrest and subsequently, with a lower oesophageal sphincter pressure of about 20 cm H2O would have been simulated. Furthermore, it is impossible to simulate changing respiratory system compliance such as during CPR, which was shown in a laboratory model. Also, we are unable to report inflation pressures, and at what pressure and tidal volume a leak occurred with each device. Although our manikin is unable to simulate the upper airway of a human perfectly in regards of sealing conditions, we suggest that peak airway pressure values in both the laryngeal mask airway and combitube group indicated an adequate seal.

In conclusion, the paediatric self inflating bag may be an option to reduce the risk of gastric inflation when using the laryngeal mask airway, and especially, the bag-valve-facemask. Both the laryngeal mask airway and combitube proved to be valid alternatives for the bag-valve-facemask in our experimental model.

Contributors
All coauthors designed the study, and collected the data. Volker Dörges and Volker Wenzel edited the first draft of the manuscript, all other coauthors subsequently made critical suggestions to the article. The final draft was read and approved by all coauthors. Volker Dörges will act as guarantor.

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Conflicts of interest: none.

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