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Evaluation of six different airway devices regarding regurgitation and pulmonary aspiration during cardio-pulmonary resuscitation (CPR) – A human cadaver pilot study☆

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ABSTRACT

Background: Chest compressions and ventilation are lifesaving tasks during cardio-pulmonary resuscitation (CPR). Besides oxygenation, endotracheal intubation (ETI) during CPR is performed to avoid aspiration of gastric contents. If intubation is difficult or impossible, supraglottic airway devices are utilized. We tested six different airway devices regarding their potential to protect against regurgitation and aspiration during CPR in a randomized experimental human cadaver study.
Methods: Five-hundred ml of 0.01% methylene-blue-solution were instilled into the stomach of 30 adult human cadavers via an oro-gastric tube. The cadavers were then randomly assigned to one of six groups, resulting in 5 cadavers in each group. Airway management was performed with either bag-valve ventilation, Laryngeal Tube, EasyTube, Laryngeal Mask (Classic), I-Gel, or ETI. Thereafter 5 min of CPR were performed according to the 2010 Guidelines of the European Resuscitation Council. Pulmonary aspiration was defined as the presence of methylene-blue-solution below the vocal cords or the ETI cuff as assessed by fiber-optic bronchoscopy.
Results: Thirty cadavers were included (14 females, 16 males). Aspiration was detected in three out of five cadavers receiving bag-valve ventilation and in two out of five intubated with LMA or I-Gel. In cadavers intubated with the LT, aspiration occurred in one out of five cases. No aspiration could be detected in cadavers intubated with ETI and EasyTube.
Conclusion: This study provides experimental evidence that, during CPR, ETI offers superior protection against regurgitation and pulmonary aspiration of gastric contents than supraglottic airway devices or bag-valve ventilation.

Introduction

Airway management, oxygenation and adequate ventilation are lifesaving procedures and therefore crucial for the treatment of critically ill patients or during cardio-pulmonary resuscitation (CPR).[1] It is important to initiate ventilation as soon as possible in all patients with inadequate respiration or respiratory arrest. Furthermore, recent data demonstrates that an increase in cerebral oxygen saturation seems to be associated with a return of spontaneous circulation in patients undergoing out-of-hospital resuscitation.[2]

Although controversially discussed, endotracheal intubation (ETI) is still considered the "gold standard" of advanced airway management.[3–5] During CPR (especially during an out-of-hospital cardiac arrest) ETI is not only performed in order to secure adequate oxygenation and ventilation, but also to avoid aspiration of gastric contents or blood. However, performing ETI requires high levels

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of skills and experience as well as regular training and practice.[6,7] Additionally, there are a number of potential risks associated with out-of-hospital ETI, e.g. pulmonary aspiration, a transfer delay of the patient to the hospital due to the need of several (maybe even unsuccessful) intubation attempts or unrecognized (esophageal) tube misplacement.[8] Difficulties with conventional ETI as well as airway-associated adverse outcomes led to the concept of "difficult airway management".[9,10] To meet this issue, various supraglottic airway (SGA) devices have been developed over the years as possible alternatives to conventional ETI.[11,12] Securing the airway with SGA devices is less invasive and much easier to perform than ETI and may help to reduce time to intubation/ventilation, especially in patients with a difficult airway.[3,13–15] Major concerns regarding the routine use of SGA devices in the pre-hospital emergency setting are potential gastric inflation (resulting in regurgitation), air leak even in experienced hands as well as a failure of protection against aspiration of gastric contents.[16–18]

Knowing that aspiration might be present in almost 25% of all dead patients,[19] it might be challenging to determine an association between the aspiration of gastric content and the airway device used in patients undergoing CPR. With the current randomized experimental study we specifically aimed at the assessment of regurgitation/aspiration of gastric contents under CPR in association with the use of the different airway devices.

Methods

Setting and population

After obtaining institutional research ethics board approval (913/2010), 30 suitable adult human cadavers were included into this study by the investigators at the Department of Pathology at the Medical University of Vienna between January 2011 and November 2012. In accordance with the institutional review board approval as well as local protocols and jurisdiction, inclusion into this cadaver trial did not require formal consenting. All human cadavers died within three hours before the study setting and were stored at room temperature (22 °C) in the interim. Exclusion criteria included known pathologies of the upper airway or upper alimentary tract (oral cavity, pharynx, larynx, esophagus and stomach), such as tracheal lesions or tumors. Cadavers were also excluded from the study if they had had any previous surgical procedure or radiation to the head, neck, chest, esophagus or stomach, which might have altered or even prevented the insertion of airway devices. Additionally, cadavers showing any of the following features were also not considered to be suitable for the current study: esophageal strictures, tracheostomy (or prior tracheostomy), infectious diseases (e.g. HIV, hepatitis, tuberculosis), body mass index greater than 45 kg/m^2, significant rigor mortis, cadavers undergoing forensic autopsy, prior CPR, signs of regurgitation or aspiration of gastric content.

Study protocol

Human cadavers were placed in supine position on the straight autopsy table. Face, mouth, teeth and upper aero-digestive tract were inspected to identify any injuries or lesions, signs of regurgitation or even aspiration of gastric content. Then all remaining gastric contents were aspirated from the stomach using a conventional gastric tube. Subsequently, 500 ml of 0.01% methylene-blue-solution (Merck Chemicals, Darmstadt, Germany) were instilled into the stomach via the gastric tube, with the latter being removed after instillation. The cadaver's face was covered with fabric in order to avoid any contamination of the face or mouth with the methylene-blue-solution. Fiberoptic bronchoscopy was performed prior to CPR in order to exclude unintentional methylene-blue staining of the pharynx or larynx.

Included cadavers were then randomly assigned to one of the following six groups receiving different types of airway management:

1. Bag valve ventilation (BVV, Ambu Spur II, Bad Nauheim, Germany).
2. Laryngeal tube disposable, size 4 (LT, King-LTS-D, VBM, Sulz, Germany).
3. EasyTube®, Ch 41 (ET, Teleflex Medical Ruesch, Research Triangle Park, NC).
4. Laryngeal Mask Airway Classic, size 4 (LMA, LMA Company North America, San Diego, CA).
5. I-Gel, size 4 (I-Gel, Intersurgical Ltd., Wokingham, England).
6. Laryngoscopy-guided endotracheal intubation (ETI) using a tube with 7.5 mm inner diameter (Mallinckrodt, Athlone, Ireland) reinforced with a Single-use malleable intubation stylet (Smiths Medical, Brunn am Gebirge, Austria).

Randomization (1:1) was based on computer-generated codes that were maintained in sequentially numbered opaque envelopes. All airway devices were inserted as recommended by the respective manufacturers by one of three experienced anesthesia consultants with the cadaver in supine position. If applicable, cuffs of the SGA and the endotracheal tube were inflated as recommended using a manometer. Correct placement, acceptable seal and adequate possibility to ventilate were confirmed by single ventilation using an anesthesia bag.

Afterwards, CPR with chest compressions was initiated in accordance with the CPR guidelines of the European Resuscitation Council (ERC) using non-interrupted chest compressions (100/min), while ventilating the cadaver with a rate of 10/min.[3] Ventilation was performed with the assigned airway device connected to a conventional single-use self-inflating anesthesia bag as recommended by the ERC: Application of rescue breath over approximately 1 s, with enough volume to make the victim's chest rise, but to avoid rapid or forceful breaths.[3] The anesthesia bag was connected to a positive end-expiratory pressure (PEEP) valve, which was set to 5 cm H_2O during the whole CPR procedure.

Cadavers assigned to the BVV-group underwent CPR without prior airway management. Chest compressions were paused during ventilation in accordance with the ERC guidelines in a ratio of chest compression/ventilation of 30:2.[3]

Assessment of presence of methylene-blue solution in the airway

After five minutes of CPR the spread of gastric content (i.e. methylene-blue solution) was assessed using a fiber-optic bronchoscope (Olympus BF 240 with light source, Olympus Europe, Hamburg, Germany). The bronchoscope was first inserted into the oral cavity and then into the trachea and the main bronchi via the ventilatory lumen of the airway device. Afterwards, a mandatory post-mortem examination was performed by independent pathologists.

Although the two terms "regurgitation" and "aspiration" are describing processes that are usually observed in patients still alive, for reasons of simplicity we decided to use the terms for the classification of the distribution of the methylene-blue found in the cadavers in the current study as well. "Regurgitation" was defined as the presence of methylene-blue-solution (as a measure of gastric content) in the esophagus and/or the laryngopharynx. Pulmonary "aspiration" was defined as the presence of methylene-blue-solution (i.e. gastric content) below the vocal cords or below the tube cuff in patients intubated with ETI, respectively.[20]