Clinical paper

Impact of the laryngeal tube as supraglottic airway device on blood flow of the internal carotid artery in patients undergoing general anaesthesia

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Abstract

Introduction: Laryngeal tubes (LT) are supraglottic airway devices routinely used in emergency airway management. During cardiac arrest in a swine model, the carotid artery blood flow is reduced after insertion of a LT. A compression of the internal carotid (ICA) artery by the inflated cuff was shown. Up to now there is no information if the LT has similar effects in humans with possible negative implications for use of the LT in case of cardiac arrest.

Objective: We hypothesized that the use of a LT in humans significantly reduces the blood flow in the ICA compared facemask ventilation. A significant reduction was defined as a 25% reduction from baseline values.

Material and methods: After induction of general anaesthesia and reaching a haemodynamic steady state (stable heart rate >50/min and mean arterial pressure >60 mmHg), blood flow within the ICA was measured via doppler sonography during pressure-controlled ventilation with facemask-, laryngeal tube- and laryngeal mask.

Results: We found no differences in the carotid blood flow. Neither between the facemask ventilation (right side 419 ± 159 ml min^{-1}, left side 355 ± 120 ml min^{-1}) and the laryngeal tube ventilation (right side 400 ± 131 ml min^{-1}, left side 384 ± 124 ml min^{-1}. p = 0.86 and p = 0.12), nor the facemask-ventilation and the laryngeal mask ventilation (right ICA 415 ± 150 ml min^{-1}, left ICA 485 ± 274 ml min^{-1}, p = 0.49 and 0.26).

Conclusions: In humans the LT does not impair blood flow of the internal carotid artery during ventilation in general anaesthesia. Further studies are needed to confirm our findings under the conditions of cardiac arrest.

Keywords: Airway management, Bag-valve-mask, Cerebral blood flow, Supraglottic airway, Resuscitation

Introduction

Laryngeal tubes (LT) are supraglottic airway devices and used routinely in emergency airway management in emergency medical services (EMS) as well as during in-hospital emergencies.[1–3] The simplified utilization and its improved protection against aspiration compared to bag-mask-ventilation (BMV) led to becoming the airway device of choice for EMS staff during cardio-pulmonary resuscitation. The main reason is a faster and more successful placement of the LT compared to endotracheal intubation.[4] The recent American Heart Association (AHA) and the European Resuscitation Council (ERC) guidelines on advanced cardiac life support recommend supraglottic airways as an option for airway management in out-of-hospital cardiac

arrest (OHCA).[5,6] For untrained providers – regarding endotracheal intubation – a LT is postulated as the device of choice.[5–7]

In a swine model for cardiac arrest however, the internal carotid artery (ICA) blood flow was reduced by 50% after the insertion of a laryngeal tube.[8] This effect was accompanied find a compression of the internal and external carotid arteries as proved by post-mortem angiogram. The proximity of the inflated cuff to the internal carotid artery could cause similar effects in human patients.

The current data of adverse events in use of LT on human is unclear. The recent AIRWAYS-2 study, with more than 9000 patients included compared the use of supraglottic airway devices with endotracheal intubation during OHCA. The study demonstrated no difference in clinical outcome.[9] In contrast, Wang et al. investigated more than 3000 patients in OHCA and showed a significantly higher 72 h survival rate when a LT was inserted in the first attempt.[10]

On the other hand, Sulzgruber et al. demonstrated that the use of LT as compared to endotracheal intubation during cardiac arrest is associated with poor 30-day survival rates and unfavorable neurological outcome.[11] While an impairment of the carotid artery flow with consecutive reduced brain perfusion caused by the LT was indeed discussed as a possible reason for this result, it remains unclear if the finding of a reduced carotid blood flow in a swine model can be transferred to humans as to different neck anatomy.

The objective of this prospective study was to measure the effect of different supraglottic airway devices on blood flow in the internal carotid artery by using the duplex sonography technique.

Material and methods

After ethical approval by the ethics committee of Hanover Medical School (ID-number 7189-2016; July 4th, 2016; committee chair: Prof. Dr. H. D. Tröger), 21 patients were enrolled into this repeated measure design study. Written informed consent was obtained from all participants.

Inclusion criteria were adult patients scheduled for elective eye surgery under general anaesthesia with the need of mechanical ventilation via a supraglottic airway device. Exclusion criteria were a diagnosed carotid stenosis of >50%, mandatory endotracheal intubation or rapid-sequence-intubation, patients under 18 y or under legal supervision. A randomization was not used.

After establishing a suitable vital sign monitoring, patients were preoxygenated with a tight-fitting face mask and an inspired oxygen concentration of 100% for at least 5 min. General anaesthesia was induced using 1.5 mg kg^{-1} propofol and 1 μg kg^{-1} remifentanil. After unconsciousness and apnea occurred, pressure-controlled ventilation via face mask (PCMV) was installed without the use of an oropharyngeal tube. The inspiratory pressure was chosen to achieve a tidal volume of 7 ml kg^{-1}. The respiratory rate was adjusted to maintain the end expiratory carbon dioxide between 35 and 45 mmHg. No muscle relaxant was administered. Anaesthesia was maintained using sevoflurane with a minimal alveolar concentration of 0.8 and a continuous remifentanil infusion with 0.2 μg kg^{-1} min^{-1}. During anaesthesia 10 ml kg^{-1} infusion of a balanced crystalloid solution (Sterofundin ISO®, BBraun, Melsungen, Germany) was administered.

After induction and reaching a haemodynamic steady state (heart rate >50/min and mean arterial pressure >60 mmHg), blood flow within the internal carotid artery was measured (7.5 MHz linear ultrasound probe in duplex Doppler ultrasound mode; Esaote MyLab 25Gold®, Esaote, Italy) with the head in midline position on a horseshoe-type headrest. The vital signs were stable among all blood flow measurements. Heart rate was measured continuously, non-invasive blood-pressure was measured in a 2 min interval. The blood volume flow was calculated from measurements of blood velocity averaged over three cardiac cycles (time-averaged velocity (TAV)) and the vessel cross-sectional areas (A) measured from the B-mode image: Volume flow = TAV × A. All measurements were performed three times on each side 1 cm cranial of the carotid bulb during (1) pressure-controlled mask-ventilation (PCMV) and (2) during laryngeal tube (LTS-D® size 4, for a height of 155–180 cm, VBM medical, Germany) and (3) laryngeal mask ventilation (Aura Gain®, size 4 for a weight from 50 to 70 kg, size 5 for a weight from 70 to 100 kg, Ambu, Germany), respectively. If no sufficient ventilation could be established, a smaller or bigger sized LMA was inserted. The doppler sample volume was placed in the center of the flow stream and broadened as much as possible without including wall noise, a 60-degree angle of insonation was used for all velocity measurements. The arithmetic mean was calculated after each measurement. After the blood flow measurements during pressure-controlled mask-ventilation the laryngeal tube was inserted, and the cuff was inflated using the provided color-coded syringe. Afterwards, the cuff pressure was reduced to a pressure of 60 mbar, according to the manufacturer's recommendation. The three measurements per side were repeated and the LT was removed, and the laryngeal mask was inserted. The cuff was inflated until no leakage was registered by the mechanical ventilator (Draeger Primus IE, Draeger, Germany). The cuff pressure was recorded. After three further recordings of the ICA blood flow per side, the patient was transferred to the operation theatre and surgery started. Correct placement of all devices was confirmed by bilateral lung auscultation and end tidal CO_2 tracing. All sonographic measurements were performed by the same experienced operator.

Sample size calculation was performed using G*Power 3.1.[12] We defined a 25% reduction of ICA blood flow to be clinically significant.[13] Normal values are 250 ml min^{-1} ± 100 ml min^{-1}. A sample size of 19 was calculated assuming an alpha error of 5% and a power of 80%. We assumed a dropout rate of 10% and therefore enrolled 21 patients.

All collected data were processed using GraphPad Prism 6.0 h (GraphPad Software, Inc., USA). Data was tested for normal distribution (Shapiro–Wilks normality test) and is presented as mean and standard deviation (S.D.) (normal distribution) or as median and interquartile range (IQR) (non-normal distribution). Differences in blood flow investigated with the two supraglottic airway devices were compared to pressure-controlled mask ventilation and calculated with Wilcoxon signed-rank test. Continuous data were analyzed using the Wilcoxon test. A p-value < 0.05 was considered statistically significant.

Results

Twenty-one patients were enrolled into this study. Demographic data and haemodynamic steady state parameters are described in Table 1.

During pressure-controlled mask ventilation ICA blood flow was 419 ± 159 ml min^{-1} on the right side and 355 ± 120 ml min^{-1} on the left side (p = 0.59). All patients received a laryngeal tube size 4. The determined blood flow during laryngeal tube ventilation was 400 ± 131 ml min^{-1} for the right side (p = 0.86) and 384 ± 124 ml min^{-1} for the left side (p = 0.12). For the third intervention 13 patients received a laryngeal mask size 5 (body weight: >75 kg) and 6

Table 1 – Demographic data and haemodynamic variables in steady state.

	n	Mean	S.D.	Median	IQR	Percentage
Demographic data						
Age [years]	21			70	16.5	
Height [cm]	21	170	6.5			
Weight [kg]	21	74.7	9.4			
Body mass index [kg/m^2]	21	25.9	2.5			
Sex (female)	21					38.1
Steady state vital signs						
Heart rate [min^{-1}]	21	61.9	10.6			
Systolic blood pressure [mmHg]	21			99.5	17	
Diastolic blood pressure [mmHg]	21	53.2	8.8			
Mean arterial pressure [mmHg]				67.7	12.2	

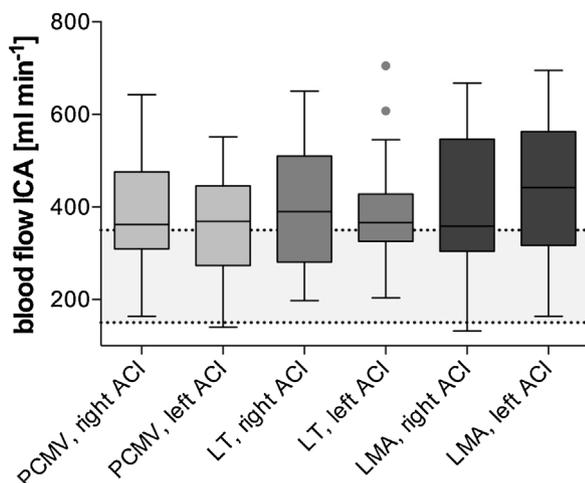S.D.: standard deviation; IQR: interquartile range.

patients a laryngeal mask size 4 (body weight: <75 kg). 2 patients were not ventilated using a LMA because of pressure of time in the OR environment. Blood flow was 415 ± 150 ml min^{-1} on the right side (p = 0.49) and 485 ± 274 ml min^{-1} in the left ICA (p = 0.26). When compared to pressure-controlled mask ventilation, no significant differences were detected. Median cuff pressure in the laryngeal tube was 60 (IQR 0) mbar and 25 (IQR 5) mbar in the laryngeal masks. Data is presented in Fig. 1.

Discussion

Our data showed no significant differences in ICA blood flow using a laryngeal tube or a laryngeal mask airway as compared to

Fig. 1 – Internal carotid blood flow.
Box-and-whisker-plots of internal carotid artery (ICA) blood flow during pressure-controlled mask ventilation, laryngeal tube ventilation and laryngeal mask ventilation; PCMV: pressure-controlled mask ventilation; LT: laryngeal tube, LMA: laryngeal mask airway; Boxplots indicate median and interquartile range, whiskers indicate 1.5 IQR. Dots show values outside 1.5 IQR. Triangles indicate values outside the whiskers. Dotted lines indicate normal range of ICA blood flow in adults. We found no statistical differences between the devices.

pressure-controlled mask-ventilation. In this prospective study, we aimed to examine the impact of supraglottic airway devices on the blood flow in the brain-perfusing internal carotid artery. Measurements were compared intra-individual, each patient undergoing pressure-controlled mask-ventilation served as his own control. These findings are in contrast with the report published by Segal et al., suggesting a significant reduction in carotid artery blood flow by using a laryngeal tube.[8] However, in their setting they investigated a swine model with different neck anatomy and thus their results are not simply transferable to the human anatomy. Furthermore, measurements were obtained during cardiopulmonary resuscitation and not during haemodynamic stability. In anaesthetized patients both investigated supraglottic airway devices seem to be save in regard to the ICA blood flow. All patients had a supernormal blood flow. A relevant limitation of our study is that we cannot transfer our finding to human patients under cardiopulmonary resuscitation. Furthermore, we excluded patients with significant ICA stenosis in whom the airway devices could have potentially detrimental effects. In clinical practice however, both devices are employed irrespective of vascular status. In our study setting no muscular blockade was performed to reduce the risk of residual paralysis after emergence from anaesthesia. As muscle relaxation is universal in cardiac arrest, an increased muscle tone might have influenced the compression of the neck vessels during the study. A no tone state could be a focus of further research.

In contrast to Colbert et al. who inflated the cuff with a pre-defined amount of air without measuring the cuff pressure,[14] we limited the cuff pressure to 60 mbar in the laryngeal tubes according to the manufactures recommendation and used the lowest possible cuff pressure during laryngeal mask ventilation. Notwithstanding this recommendation, the application of a pre-defined amount of air without measuring the cuff pressure is common practice in the prehospital emergency setting. The use of a color coded standard accessory syringe for the application of air frequently results in excessive cuff pressure values exceeding 100 mbar.[1,15] Further studies are needed to evaluate the incidence of disclaiming manufacturers recommendation in practice and the impact of this excessive high cuff pressures on the ICA blood flow. In the last years, manufacturers of supraglottic airway devices recommended to reduce the cuff pressure whenever possible to reduce adverse effects like tissue hypoperfusion and possible tissue necrosis. This may also cause the carotid blood flow remaining stable.

Sulzgruber et al. showed that the use of LT as compared to endotracheal intubation during cardiac arrest is associated with poor 30-day survival rates and unfavorable neurological outcome.[11] Interestingly, there was no significant impairment in survival and neurological outcome if patients received endotracheal intubation after initial laryngeal tube ventilation on scene.[11] This may indicate that the reason for a poor outcome is not an immediate time-critical process like an acute and significant reduction of the carotid blood flow. A possible explanation for this change in outcome after endotracheal intubation may be an aspiration or insufficient ventilation related to throat swelling. Indeed, the study from Sulzgruber found the lowest readings in peripheral pulse oximetry within the LT group and interpreted these findings as a surrogate parameter for insufficient ventilation. On the other hand, Wang et al. demonstrated a significant advantage of LT as compared to endotracheal intubation in survival of OHCA. Interestingly, the observed first attempt success rate of endotracheal intubation in that study was only 51% and thus lower than reported in other meta-analyses.[10,16] The time to first airway attempt was reduced by 2.7 min in the LT group and the number of unsuccessful intubation attempts was lower in the LT group. Fewer attempts and a time reduction for airway management is associated with less interruptions in chest compressions, e.g. possibly the main reason for a better survival in the LT group. Nevertheless, endotracheal intubation can be a time critical procedure in OHCA. Jabre et al. showed no difference in outcome when comparing bag-mask ventilation versus endotracheal intubation during OHCA.[17] Considering our data, an impairment of the carotid blood flow caused by a LT may not be a relevant effect for OHCA airway management and patient outcome. However, the airway device should be selected depending on the individual provider and concerning the time critical resource management and human factors in OHCA airway management.[18]

Conclusions

Neither the laryngeal tube nor the laryngeal mask airway impairs ICA blood flow during ventilation in anaesthetized patients, if the cuffs are inflated according to the recommended cuff pressures. We cannot fully exclude a detrimental effect of the laryngeal tube cuff during cardiac arrest in humans. Further studies, especially under the condition of cardiac arrest or low-flow are needed to rule this out.

Conflicts of interest and source of funding

None. No external funding was received.

Contributions

HE,**LS** and **TP** were responsible for study design, conduct of the study (patient recruitment, data collection), data analysis and manuscript preparation and revision. The Authors **HE** and **LS** contributed equal to this work.

OO was responsible for the conduct of the study (patient recruitment, data collection) and revising the manuscript revision.

AL was responsible for revising the manuscript.

All authors read and approved the final manuscript.

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