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# Alternative concept of ventilation during cardiopulmonary resuscitation (CPR) in dental chairs

## Summary

Infrequent training of artificial ventilation in dental facilities implies poor performance of this procedure under CPR. Gastric inflation is a significant issue when ventilation is performed on an unprotected airway. An Easy Grip® (EG) Bag-Valve-Mask Resuscitator, a Laryngeal Tube (LT), size #5, and a SMART BAG® (SB) resuscitator, a pressure-limiting device, were tested to assess the respiratory effects especially focussing on prevention of gastric inflation during simulated CPR.

Twenty academic dental staff members performed ten ventilations on a manikin during CPR by use of EG, LT and SB in a randomized order. In twelve experiments the oesophageal sphincter pressure was adjusted to 15 mbar (best case), in eight experiments to 0 mbar (worst case scenario).

Best case scenario median tidal volume distributions achieved by EG (median 144 ml) and LT (75 ml) did not differ, whereas differences were found between EG and SB (31 ml;  $p=0.055$ ) as well as between SB and LT ( $p=0.042$ ). None of the values met recommended ranges. Almost no gastric inflation occurred. Worst case scenario ventilation by use of the LT resulted in profoundly lower median gastric inflation volumes (median 13 ml) compared to SB (median 288 ml;  $p=0.008$ ) and EG (800 ml;  $p=0.008$ ). Median tidal volume distributions also differed between LT (225 ml) vs EG (100 ml) ( $p=0.016$ ) and LT vs SB (19 ml) ( $p=0.008$ ). Chest compression was delayed in ten experiments by LT insertion for 28 s (median). In a later stage of CPR or in case of mask ventilation difficulties, the LT may serve as a helpful tool in dental facilities. CPR training must focus on the importance of chest compression which must not be discontinued if an LT is inserted. The SB might gain value if higher tidal volumes are achieved, exerting a higher risk of gastric inflation.

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## Introduction

At present, it is unclear how often situations with cardiac arrest occur in dental chairs.

Nevertheless, alertness towards unexpected cardiac events during dental treatment is required. Furthermore, the request for preparedness of the teams in dental facilities to properly interact with cardiac emergencies is warranted. This refers to a readiness to perform appropriate cardiac life support including cardiopulmonary resuscitation (CPR) with adequate ventilation.

The target of ventilation is a visible chest rise to achieve a tidal volume between 500 and 600 ml per breath. Ventilation is performed intermittently at a ratio of two ventilations which interrupt thirty chest compressions (AHA 2005, HANDLEY et al. 2005). Infrequent training and only anecdotal use of bag-valve-mask ventilation in dental facilities, however, result in a poor performance of this type of ventilation technique in real emergencies (GONZAGA et al. 2003, GRAHAM & SCOLLON 1996).

A common problem arising when CPR is performed by conventional bag-valve-mask ventilation as well as by mouth-to-mouth ventilation is accidental gas inflation of the stomach. This is a significant issue, not only due to the danger of regurgitation of gastric content, subsequent aspiration and damage to the respiratory epithelium, but also due to a reduction of pulmonary compliance resulting in reduced oxygen delivery to tissues (AHA 2005, WENZEL et al. 1998). Thus, improvements are warranted to reduce gastric inflation on the one hand and maintain or even enhance tidal volume on the other. It is assumed that the use of pharyngeal ventilation adjuncts such as the Laryngeal Tube enhance ventilation performance capabilities even in minimally trained individuals (KETTE et al. 2005).

The aim of the present study was to test alternative devices regarding the performance of tidal volume application to the lung and prevention of gastric inflation during artificial ventilation in a simulated CPR situation. The first hypothesis to test was that lower gastric inflation volumes will result by use of these devices when compared to a conventional bag-valve-mask device.

The second hypothesis was that no differences in tidal volumes will result with all devices tested.

## Materials and Methods

After approval by the local ethics committee and after having obtained informed consent, twenty subjects recruited from a group of first year resident dentists and dental students (University of Zurich, ZZMK) trained in cardiopulmonary resuscitation on mannequin devices volunteered to participate. None of them had been involved in a real CPR situation before. The study protocol included randomized testing within an experimental resuscitation setting in a dental chair.

All of the participants had been educated in CPR within the last year but not within a time frame shorter than six months prior to the test.

The manikin used in the experimental setting was an Ambu Man (Ambu, Glostrup, Denmark).

The ventilation part of resuscitation was performed using an airway management training mannequin (Bill, VBM, Sulz a.N., Germany), which had been validated earlier for the measurement of respiratory and gastric inflation volumes (DOERGES et al. 2001). It was modified by a ventilation surveillance system connected to a volumeter and a modified gastric inflation detector connected to another volumeter (Fig. 1).

The artificial lung connected to the ventilation surveillance system had a compliance of  $C = 60 \text{ ml}/0.1 \text{ kPa}$  ( $60 \text{ ml}/\text{mbar}$ ) measured by use of an intensive care respirator Evita XL (Dräger, Lübeck, Germany).

### Test devices

An Easy Grip® (O-Two Medical Technologies Inc, Mississauga, Ontario, Canada) disposable bag-valve-mask resuscitator (Fig. 2a) served as the standard bag-valve-mask device. The second device tested was a SMART BAG® (O-Two Medical Technologies Inc, Mississauga, Ontario, Canada) disposable bag-valve-mask re-

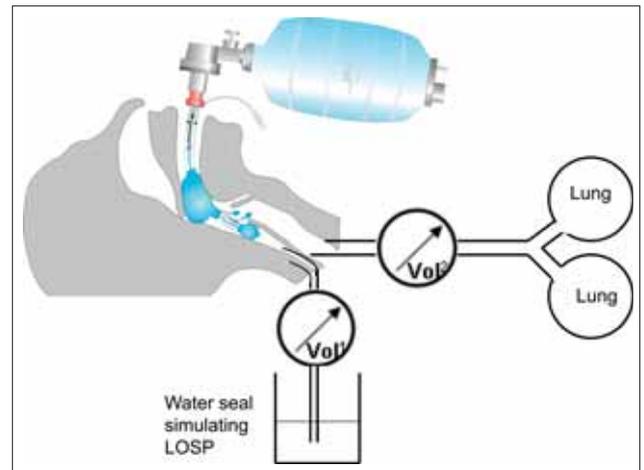


Fig. 1 Manikin device for investigating ventilation: Bill (VBM, Sulz a. N., Germany); a water seal simulates lower oesophageal sphincter pressure (LOSP). Volumeter 1 (Vol<sup>1</sup>) measures stomach inflation, Volumeter 2 (Vol<sup>2</sup>) the gas volume entering the upper airway. The part of the drawing which includes the Laryngeal Tube was kindly provided by VBM.

suscitator (Fig. 2b). The Easy Grip® without the mask was used in combination with the third device tested, a Laryngeal Tube (VBM, Sulz a.N., Germany), size #5 (Fig. 3).

### Test procedure

The study participants ventilated the manikin ten times using a technique demonstrated briefly before the test. One rescuer had to perform ventilation whereas the other rescuer's task was to intermittently perform chest compressions. The ratio was two ventilations : 30 chest compressions (AHA 2005, HANDLEY et al. 2005) according to the guidelines. During ten ventilation cycles, tidal volumes administered were measured as well as the gastric inflation volumes during each ventilation procedure. Lower oesophageal sphincter pressure (LOSP) values of the manikin were adjusted to 15 and zero mbar, respectively. Volumeter recordings were videotaped for later analysis.

### Statistics

Median values of the distribution of all tidal volumes and – if occurring, also gastric inflation volumes – detected during ventilation by each rescuer using the respective device at a distinct LOSP setting were calculated. The distribution of the median values achieved by all rescuers with the respective device was expressed by box-and-whisker plots. Comparisons of the different distributions were made by exact Wilcoxon test matched pairs statistics using the Excel add-in Analyse-it (Analyse-It Software Ltd., Leeds, England, UK). Statistically significant differences between data distributions were considered at p-values lower than 0.05.

## Results

Twenty academic dental staff volunteers (twelve males, eight females) performed CPR training. Eight subjects were included in a setting with an open oesophageal sphincter simulator, whereas the sphincter tone had been adjusted to 15 mbar in a group of twelve subjects tested. Tidal and gastric inflation volumes achieved by use of the three different systems under the different conditions are depicted in Figs. 4a–c. In the second group, due to a failure of the recording system during ventilation

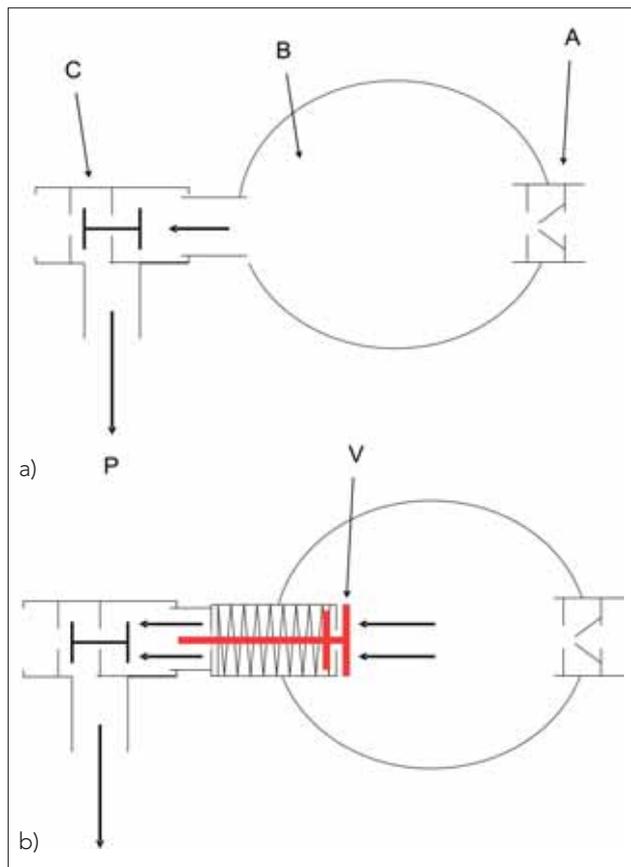


Fig. 2 Schematic drawings: a) Easy Grip® disposable bag-valve-mask resuscitator. This standard self refilling bag (B) is equipped with a one-way valve serving as a gas inlet only (A). On the exit side of the bag it is connected to a so-called non-rebreather valve (C). This valve consists of a membrane that is designed to direct the gas leaving the bag to the patient (P) via a mask or an endotracheal tube. The second function of the valve is to direct expiration gas from the patient to the ambient air. Thereby, a refill of the bag by expiration gas from the patient is avoided. b) SMART BAG® disposable bag-valve-mask resuscitator. It limits excessive flow of gas into the patient's airway, thereby reducing the risk of gastric inflation. The system limits the pressure in the patient's airway to below 19 mbar. This is achieved by a specially designed pressure reducing valve V.

of two subjects ventilating with the conventional bag-valve-mask device, these values were considered drop outs and the respective measurements were not included in the statistical data analysis. Gastric inflation was observed only twice in the setting with the oesophageal sphincter opening pressure adjusted to 15 mbar. These inflations, 20 and 200 ml, occurred during SMART BAG® ventilation. Tidal volumes administered to the lung were higher with Laryngeal Tube (median 75 ml, 3<sup>rd</sup> quartile 200 ml) and Easy Grip® (median 144 ml, 3<sup>rd</sup> quartile 235 ml) bag-valve-mask resuscitator compared to the SMART BAG® resuscitator (median 0, 3<sup>rd</sup> quartile 31 ml) with  $p=0.042$  when Laryngeal Tube was compared and  $p=0.055$  when Easy Grip® was compared to SMART BAG®. Laryngeal Tube and Easy Grip® results did not reveal any significant differences ( $p=0.49$ ) (Fig. 4a). In the setting with an LOSP adjusted to 0 mbar gastric inflation volumes were markedly greater by use of the Easy Grip® bag-

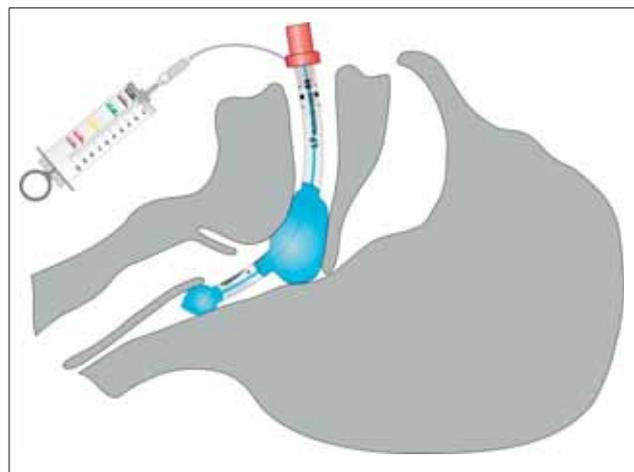


Fig. 3 Schematic drawing of the Laryngeal Tube. This tube serves as a pharyngeal airway adjunct. It consists of a tube with a double cuff. One part of the cuff is designed to be positioned in the oesophageal entrance – to separate it from the pharyngeal space – whereas the other, larger, part serves as a pharyngeal blocking device which prevents air inflated into the tube from escaping via the pharynx. The cuffs are filled with air once the tube has been inserted into the correct position. Drawing kindly provided by VBM.

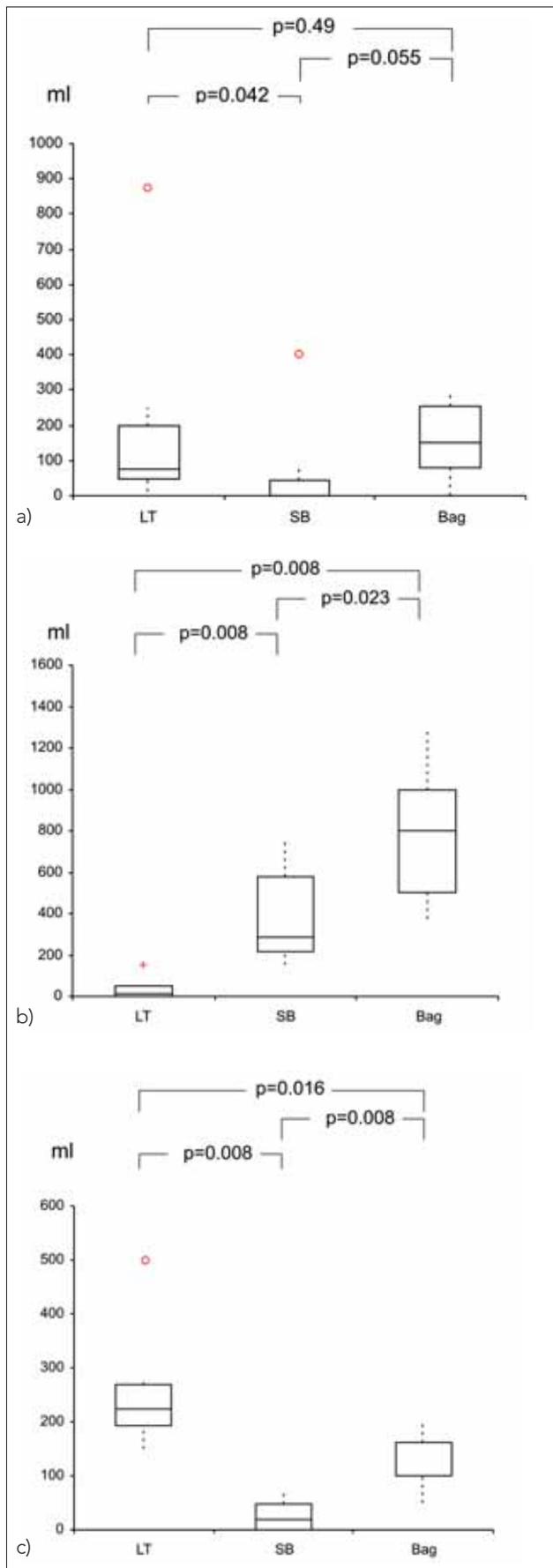
valve-mask resuscitator (median 800 ml, 3<sup>rd</sup> quartile 1000 ml;  $p=0.008$ ), as well as by use of the SMART BAG® (median 288 ml, 3<sup>rd</sup> quartile 525 ml;  $p=0.008$ ) compared to ventilation by use of the Laryngeal Tube (median 13 ml, 3<sup>rd</sup> quartile 50 ml). Distributions of gastric inflation volumes caused by Easy Grip® and SMART BAG® were also different ( $p=0.023$ ) (Fig. 4b). The median tidal volumes achieved by use of the Laryngeal Tube (median 225 ml, 3<sup>rd</sup> quartile 275 ml) differed also from the SMART BAG® (median 19 ml, 3<sup>rd</sup> quartile 41 ml;  $p=0.008$ ) and Easy Grip® results (median 100 ml, 3<sup>rd</sup> quartile 138 ml;  $p=0.016$ ). SMART BAG® and Easy Grip® results were also different ( $p=0.008$ ) (Fig. 4c).

During Laryngeal Tube insertion no chest compressions were performed in ten CPR experiments, which resulted in a median delay of 28 seconds. In the rest of the experiments either one or both rescuers performed chest compressions during Laryngeal Tube insertion.

## Discussion

The main result of the present study was that the Laryngeal Tube markedly reduced gastric inflation in case of an open oesophageal sphincter. It provides effective protection against gastric inflation even in extreme situations, such as a low oesophageal sphincter pressure reduced to zero. However, tidal volumes achieved by use of the different systems did not meet the recommended range of 500–600 ml. Under unfavourable conditions, i. e., a zero sphincter opening pressure, the Laryngeal Tube may be advantageous due to the profoundly reduced gastric inflation, resulting in a lower risk of aspiration and impairment of ventilation, respectively.

Bag-valve ventilation of the unprotected airway by use of a mask bears the risk of gastric inflation. The amount of ventilation gas directed to the lungs to generate a tidal volume is influenced by respiratory system compliance (SAFAR 1958), resistance of the airway (WEILER et al. 1997) and lower oesophageal sphincter



pressure (RUBEN et al. 1961, WEILER et al. 1995). Furthermore, inspiratory flow and airway pressure depending on the rescuer's performance of ventilation contribute to the amount of gas directed to the stomach (WENZEL et al. 2001).

It has been shown in animal experiments that lower oesophageal sphincter pressure decreases during the early phase after onset of cardiac arrest from 2.0–0.33 kPa (20–3.3 mbar or cm H<sub>2</sub>O) (BOWMAN et al. 1995). A loss of oesophageal sphincter pressure after respiratory arrest has been shown in intensive care patients with devastating neurotrauma after discontinuing ventilatory support. This loss of sphincter pressure well precedes cardiac arrest. At the time of cardiac arrest LOSP averaged 0.5 kPa (5 mbar), but even lower pressures reaching the level of zero were observed (GABRIELLI et al. 2005). It has to be assumed that a similar dynamic loss of this protective mechanism occurs in out-of-hospital cardiac arrest patients to the same extent and comparably fast. However, even in the non-emergency situation of elective general anaesthesia induction, gastric inflation has been observed at airway pressure levels much lower than 20 mbar (RUBEN et al. 1961, WEILER et al. 1995).

Furthermore, a loss of pulmonary compliance from about 100 ml/0.1 kPa to about 50 ml/0.1 kPa (100–50 ml/mbar) has been described in this early phase after cardiac arrest (ORNATO et al. 1983). This phenomenon further favours a distribution of ventilation volume towards the stomach.

The compliance of the lung simulator used here, therefore almost equals the compliance of a cardiac arrest victim. A direction of gas to the stomach was not observed with either device with oesophageal sphincter pressure adjusted to 1.5 kPa (15 mbar). However, the tidal volumes that were achieved by use of the SMART BAG® were lower compared to the standard bag (Easy Grip® in this case) or the Laryngeal Tube in either case. The reason for this could be the increased resistance of the bag indicating to the rescuer that the pressure administered on the bag is too high. On the other hand, attempts to reduce this pressure by the rescuer may have caused the lower tidal volumes.

#### Methodological limitations

The present experimental setting has several limitations. The manikin model as usual cannot exactly reproduce the facial structures as well as the respiratory and oesophageal sphincter mechanics of a patient in the situation of a cardiac arrest.

It cannot be excluded that the experimental setting has favoured mask ventilation capabilities, gastric inflation or reduced pulmonary ventilation due to the chosen configuration.

Furthermore, to the best of our knowledge, it has not been examined in which way pulmonary compliance and lower oesophageal sphincter pressure might influence a rescuer's ventilation performance. There was no stomach compliance in the present model, as the stomach was represented by the air downstream to the water seal in one setting and just by air in

*Fig. 4 Simulated two rescuer resuscitation by use of Laryngeal Tube (LT), SMART BAG® (SB) bag-valve-mask resuscitator and Easy Grip® (Bag) bag-valve-mask resuscitator. a) Tidal volumes administered to the test lung at an oesophageal sphincter opening pressure adjusted to 15 mbar, b) gastric inflation volumes and c) tidal volumes administered at an oesophageal sphincter opening pressure adjusted to 0 mbar.*

*Boxplots: Interquartile Range 75–25%; divided by median. Cross (+) indicates near outlier – observation more than 1.5 IQRs from the quartile. Circles (o) indicate far outliers – observations 3.0 IQRs from the quartiles.*

the other. The water seal itself was chosen as it was assumed that this type of pressure generating system has no delayed opening in comparison to a spring loaded pressure relief valve, such as a peep valve. Thereby, an overrun of the relief mechanism by very high airflows might occur. To simulate this overrun, the opening pressure of the oesophageal sphincter was set at zero in the second setting. There might be a delay in opening of the lower oesophageal sphincter in comparison to the water seal as the mucosal layers of the oesophagus may stick together depending on the grade of mucus lubrication, and this might add to the closing effect of the muscular tone as well. Thus, gastric inflation may have been overestimated in our model.

The Laryngeal Tube and the SMART BAG® have already been tested in clinical settings (WAGNER-BERGER et al. 2003, KETTE et al. 2005). Promising results have already been confirmed under controlled conditions such as anaesthesia induction (WAGNER-BERGER et al. 2003) as well as under cardiopulmonary resuscitation (KETTE et al. 2005, ASAI et al. 2003). It may be assumed that the use of these systems by the participants in this study might have resulted in a better performance in patients in case of anaesthesia induction. However, these patients usually have a higher oesophageal sphincter opening pressure (RUBEN et al. 1961, WEILER et al. 1995).

The Laryngeal Tube has been tested in out-of-hospital resuscitation by nurses and it was successfully inserted within two attempts in 90% of the patients (KETTE et al. 2005).

Successful results by use of the Laryngeal Tube have also been described in cases of a pharyngeal airway obstruction by WINTERHALTER et al. (2005), who managed difficult airways in patients with pharyngeal and laryngeal tumors.

The present study evaluated the safety and efficacy of a bag-valve-mask ventilation device supplemented with a pressure and flow reducing feature as well as an established pharyngeal ventilation adjunct. It has been shown that in extreme situations with an oesophageal sphincter pressure reduced to zero both devices significantly reduce gastric inflation with the Laryngeal Tube revealing maximum efficacy. A patient study revealed a leak of this device exceeding a median pressure of 3.0 kPa (30 mbar) (ASAI et al. 2000), which may offer a significant margin of protection against gastric inflation.

The risk of gastric inflation strongly depends on the situation. Initially, a fasting victim may be at lower risk than a person having just stopped food intake when the cardiac arrest occurred. Furthermore, after a longer time interval after cardiac arrest, LOSP may be assumed to be extraordinarily low. Thus, it is assumed that the protective effect of the laryngeal tube may be advantageous in an out-of-hospital reality as well.

The tidal volumes administered in this study were far below the recommended levels. Repeated training may improve rescuers' performance regarding application of adequately dosed tidal volumes. Furthermore, it has to be kept in mind that it is of utmost importance not to interrupt chest compressions during insertion of pharyngeal ventilation adjuncts such as the Laryngeal Tube. In the setting described this would mean to start with bag-valve-mask ventilation by use of a conventional device and chest compressions performed intermittently. It may be advisable to change to Laryngeal Tube ventilation either in case of difficulties with mask ventilation or at a later stage during CPR. Chest compressions must not be interrupted during Laryngeal Tube insertion. Once the Laryngeal Tube has been inserted, it is allowed to simultaneously ventilate and perform chest compressions (AHA 2005, HANDLEY et al. 2005).

## Conclusion

To conclude, it can be stated that tidal volumes were not different by use of the conventional bag-valve-mask system and ventilation via Laryngeal Tube. The SMART BAG® did not offer measurable advantages regarding pulmonary ventilation. It might gain value if higher tidal volumes would be achieved, exerting a higher risk of gastric inflation. In a later stage of CPR or in case of mask ventilation difficulties, the Laryngeal Tube may serve as a helpful tool during CPR in dental facilities even in case of intrinsic pharyngeal airway obstruction by swelling e.g. caused by infection. However, regular training with this device is necessary as well as with conventional bag-valve-mask systems to ensure adequate ventilation. Furthermore, training with the Laryngeal Tube has to focus on the importance of chest compression which must not be discontinued during insertion of this tool.

## Zusammenfassung

Unregelmässige Übung der Beatmung in zahnärztlichen Einrichtungen lässt eine insuffiziente Durchführung während CPR vermuten. Eine Magenblähung ist ein relevantes Problem bei der Beatmung des ungesicherten Atemweges.

Ein Easy Grip® (EG) Bag-Valve-Mask Resuscitator, ein Larynx-tubus (LT) #5, und ein SMART BAG® (SB) Resuscitator, ein druckreduzierendes System, wurden im Hinblick auf die Beatmung und die Verhinderung einer Magenblähung während CPR geprüft.

Zwanzig akademische Angehörige einer Zahnklinik führten die Beatmung während eines CPR-Trainings mit einem eingestellten Oesophagus-Sphincter-Öffnungsdruck von 15 mbar (12 Personen; best case) bzw. 0 mbar (acht Personen; worst case) durch. Die Verteilungen der Best-Case-Szenario-Tidalvolumina durch EG (Median 144 ml) und LT (Median 75 ml) unterschieden sich nicht, während zwischen EG und SB (31 ml;  $p=0.055$ ) sowie SB and LT ( $p=0.042$ ) Unterschiede bestanden. Keiner der Werte erreichte den empfohlenen Bereich. Magenblähung wurde kaum beobachtet. Die Worst-Case-Szenario-Beatmung durch LT ergab eine deutliche Reduktion der Magenblähung (Median 13 ml) versus SB (288 ml;  $p=0.008$ ) und EG (800 ml;  $p=0.008$ ). Die Mediane der Verteilungen der Tidalvolumina unterschieden sich zwischen LT (225 ml) und EG (100 ml) ( $p=0.016$ ) sowie LT und SB (19 ml) ( $p=0.008$ ). Die Herzdruckmassage wurde in zehn Tests durch die LT-Einführung um 28 s (Median) verzögert. Im späteren Stadium der CPR oder bei Schwierigkeiten der Maskenbeatmung kann der LT für zahnärztliche Praxen ein Hilfsmittel darstellen. Das CPR-Training muss aber die Wichtigkeit der kontinuierlichen Herzdruckmassage hervorheben. Der SB könnte in der Wertigkeit steigen, wenn höhere Tidalvolumina erzielt werden, da dann ein höheres Risiko einer Magenblähung besteht.

## Résumé

Un manque d'entraînement à la ventilation artificielle dans le cadre d'un cabinet dentaire peut conduire à une mauvaise performance lors d'une réanimation cardio-pulmonaire (RCP). L'inflation gastrique est une conséquence fréquente en cas de ventilation en condition de voies aériennes non sécurisées. Un Easy Grip® (EG) Bag-Valve-Mask Resuscitator, un Tube Larynge (LT) de taille #5, ainsi qu'un Smart Bag® (SB) Resuscitator, outil limitant la pression, ont été testés. La prévention d'une inflation gastrique lors d'un exercice de RCP a, en particulier, été analysée.

Vingt membres du corps académique d'une clinique dentaire ont procédé à dix ventilations d'un mannequin durant un exercice de RCP en utilisant le EG, le LT et le SB dans un ordre randomisé. Pour douze tests, la pression du sphincter œsophagien a été ajustée à 15 mbar (situation favorable) et à 0 mbar (situation défavorable) pour les huit autres. Lors de la simulation d'un cas favorable, les distributions des volumes d'insufflations atteintes avec EG (médian 144 ml) et LT (75 ml) ne montraient pas de différence, tandis que des différences significatives ont été trouvées entre EG et SB (31 ml:  $p=0,055$ ), tout comme entre SB et LT ( $p=0,042$ ). Aucune de ces valeurs n'atteignait le niveau souhaité. Presque aucune inflation gastrique n'a été observée. En simulation de ventilation en situation défavorable, les insufflations en utilisant le LT donnaient des valeurs largement inférieures (médian 13 ml) en comparaison avec SB (médian 288 ml;  $p=0,008$ ) et EG (800 ml;  $p=0,008$ ). La distribution des volumes insufflés était également différente entre LT (225 ml) vs EG (100 ml), ( $p=0,016$ ) et LT vs SB (19 ml), ( $p=0,008$ ). Pour dix des tests d'utilisation de LT, le massage thoracique a été retardé de 28 s (médian). Dans une phase ultérieure de RCP ou en cas de difficulté de ventilation au masque, le LT pourrait servir d'outil utile dans le cadre d'un cabinet dentaire. Les exercices de RCP devraient focaliser sur l'importance de ne pas interrompre le massage thoracique pour insérer un LT. Le SB pourrait être intéressant pour obtenir des volumes d'insufflation plus élevés, mais avec un plus grand risque d'inflation gastrique.

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