BJA

British Journal of Anaesthesia, 118 (4): 618–24 (2017)

doi: 10.1093/bja/aex035
Respiration and the Airway

Comparison of effectiveness of two commonly used two-handed mask ventilation techniques on unconscious apnoeic obese adults

M. Fei[1,2], J. L. Blair[2], M. J. Rice[2], D. A. Edwards[2], Y. Liang[2], M. A. Pilla[2], M. S. Shotwell[3] and Y. Jiang[2,*]

[1]Department of Anaesthesia, Zhongshan Hospital, Fudan University, Shanghai, People's Republic of China, [2]Department of Anaesthesiology and and [3]Department of Biostatistics, Vanderbilt University Medical Center, 1301 Medical Center Drive, 4648 TVC, Nashville, TN 37232-5614, USA

*Corresponding author. E-mail: yandong.jiang@vanderbilt.edu

Abstract

Background. Mask ventilation and tracheal intubation are basic techniques for airway management and mutually inclusive rescue measures to restore ventilation. The aim of this study was to compare the effectiveness of mask ventilation between two commonly used techniques of two-handed mask ventilation in obese unconscious apnoeic adults.

Methods. Eighty-one obese adults received mask ventilation after induction using C-E clamp and modified V-E clamp techniques in a randomized crossover manner. Mechanical ventilation was provided using a pressure-control mode, at a rate of 10 bpm, with an inspiratory-to-expiratory time ratio of 1:2 and a pre-set plateau airway pressure of 20 cm H_2O. The primary outcome was expired tidal volume.

Results. The BMI for the subjects was 37 (SD 4.9) kg m^{-2}. The failure rates for mask ventilation (tidal volume≤anatomical dead space) were 44% for the C-E technique and 0% for the V-E technique ($P<0.001$). Tidal volume was significantly lower for the C-E than the V-E technique [371 (SD 345) *vs* 720 (244) ml, $P<0.001$]. The peak airway pressures were 21 (SD 1.5) cm H_2O for the C-E technique and 21 (1.3) cm H_2O for the V-E technique.

Conclusions. Mask ventilation using the modified V-E technique is more effective than with the C-E technique in unconscious obese apnoeic adults. Subjects who fail ventilation with the C-E technique can be ventilated effectively with the V-E technique.

Clinical trial registration. NCT02580526.

Key words: airway obstruction; difficult airway; mask ventilation; obesity; pressure-controlled ventilation

Nearly all general anaesthesia patients require mask ventilation for a certain time period after intentional apnoea is achieved. Unintentional apnoea, secondary to cardiac arrest or trauma, often requires mask ventilation and may frequently occur outside the operating room, in the emergency room, or prehospital field resuscitation. Failure to achieve effective mask ventilation can be rescued by successful intubation, but difficult mask ventilation and difficult intubation often occur concurrently,[1] which is catastrophic, often leading to permanent brain damage or death.[2] Although the guidelines on airway management for

Editorial decision: January 13, 2017; **Accepted:** February 3, 2017

Editor's key points

- In a randomized crossover design, the efficacy of manual mask ventilation was compared between two methods of mask ventilation using both hands ('C-E' and 'V-E' techniques), in obese patients.
- Compared with the C-E technique, the V-E technique was associated with a lower failure rate and greater tidal volume.
- In obese patients, mask ventilation using the V-E technique is preferred.

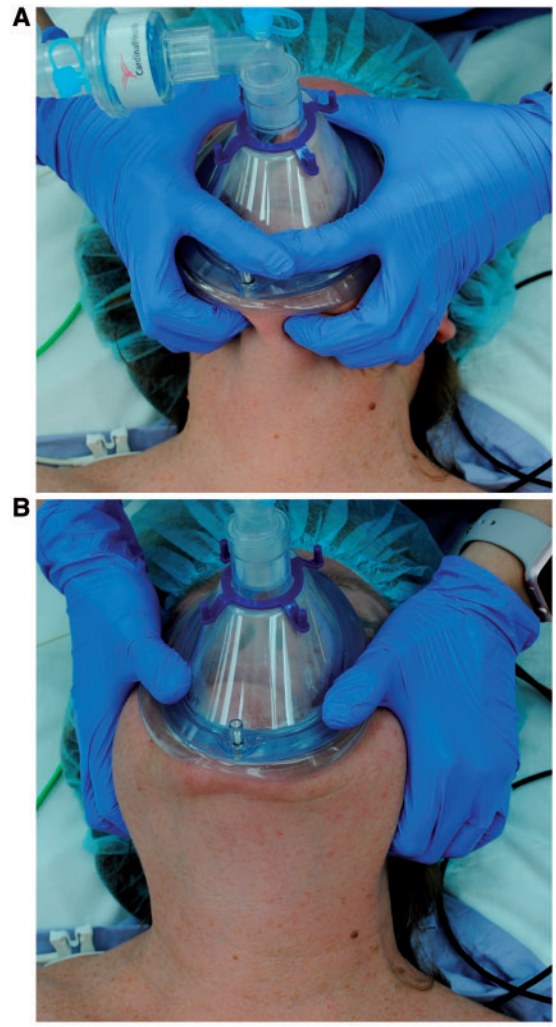

Fig 1 Twohanded bag-mask ventilation technique[s]. (A) The C-E technique. (B) The V-E technique. With the C-E technique, a jaw-thrust is performed by placing the operator s thumbs [and index fingers] on the face[mask] while simultaneously hooking the anterior mandible forward with the 3rd 5th fingers of both hands, increasing central pressure onto soft tissues into the airway. For the V-E technique, the face mask is held firmly over the face with the length of the thumbs along the sides of the mask while simultaneously performing a two-handed jaw thrust maneuver with the index and second fingers behind the angle of the mandible with mouth open. A chin lift is performed, applying anterior force to the mandible with caudal pressure on the mask..

anaesthesia and field resuscitation have been continuously improved, the Emergency Airway Algorithm focuses primarily on tracheal intubation rather than mask ventilation.[3 4] In practice, providing effective mask ventilation in a timely manner continues to be a great challenge.[5] Even though most clinicians understand that effective mask ventilation and tracheal intubation are mutually inclusive rescue methods, optimizing the skill of mask ventilation is largely under-appreciated. Clinicians often make great effort to intubate while unintentionally compromising ventilation and oxygenation.[6] Additionally, it is particularly challenging to intubate victims during field resuscitation, where intubation commonly takes place concurrently with continuous chest compressions. In fact, the failure rate of intubation during field resuscitation is 10–22%.[7 8] Thus, the importance of optimizing the skill of mask ventilation should be emphasized, because effective mask ventilation can indeed minimize or reverse hypoxia, particularly if timely successful intubation is impossible.

The conventional teaching of mask ventilation uses one-handed mask (C-E) ventilation. If ineffective, then a two-handed technique is recommended, because two-handed approaches provide a better mask-to-face seal[9 10] and produce greater tidal volumes.[11 12] However, there are two commonly used techniques of two-handed mask ventilation, the C-E technique (Fig. 1A) and the V-E technique (Fig. 1B). The C-E technique applies the mask by forming a 'C' shape with each thumb and index finger over each side of the mask while the third, fourth, and fifth fingers of both hands lift the mandible toward the mask in a three-fingered 'E' shape. In contrast, the V-E technique uses the thumbs and the eminence of each hand placed over each side of the mask, while the second to fifth digits pull the jaw upward, again forming an 'E' shape.[13] These two techniques are the last rescue measures for impossible intubation before surgical intervention is used. It is unknown whether both techniques are attempted in practice, or if one is preferred over the other. Although one study has reported marginal superiority of the V-E technique over the C-E technique in novice care providers, the comparative efficacy of the two techniques has not been evaluated systemically.[10] Enabling clinicians to optimize their mask ventilation skills should improve the quality of ventilation and thus oxygenation, and may improve downstream outcomes. The primary aim of this study was to determine and compare the efficiency of mask ventilation in obese adult subjects by using either the C-E technique or the modified V-E technique.

Methods

This study was approved by the Institutional Review Board of Vanderbilt University Medical Center, registered at ClinicalTrials.gov (NCT02580526), and was conducted between August 6, 2015 and February 24, 2016. A total of 103 subjects >17 yr of age, requiring general anaesthesia, with a BMI >30 kg m^{-2}, were recruited from the main operating rooms of Vanderbilt University Medical Center. The exclusion criteria included the following: (i) untreated ischaemic heart disease; (ii) acute and chronic respiratory disorders, including chronic obstructive pulmonary disease and asthma; (iii) ASA physical status classification ≥IV; (iv) emergency surgery; (v) induction requiring rapid sequence for intubation; (vi) pregnant women; and (vii) patients requiring an awake intubation.

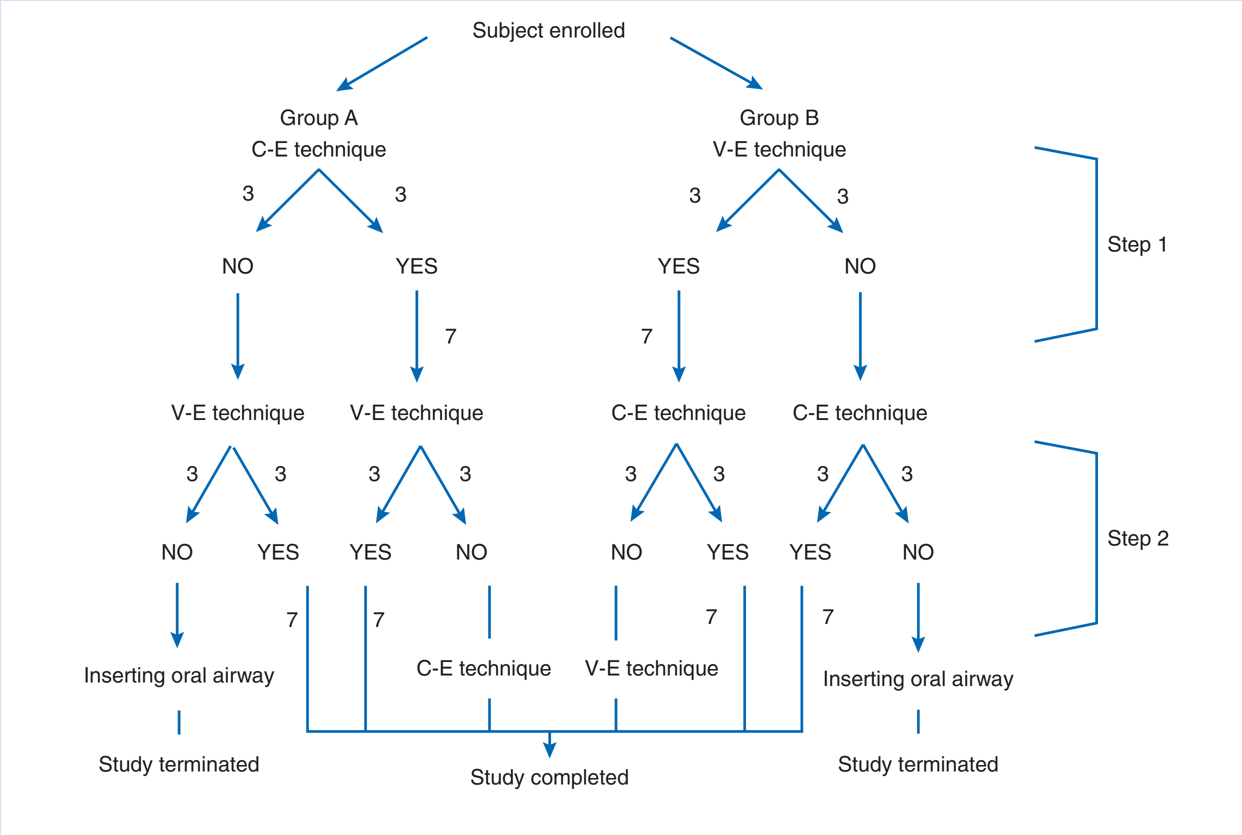

Fig 2 The algorithm of the study procedure. The numbers listed on the chart represent the number of breaths. At each Step, 10 breaths were targeted. NO, ventilation was not effective as assessed clinically; YES, ventilation was effective as assessed clinically.

Study procedure

The operators performing mask ventilation were familiar with bag–valve mask ventilation, including certified registered nurse anaesthetist (CRNA) students, anaesthesia resident physicians, and CRNAs. All the operators were not part of the study team. The operators were provided with brief instructions before to induction to demonstrate the two techniques, with a photograph for each, as shown in Fig. 1A and B.

After providing informed consent, the subjects received premedication in the usual manner. Subjects were placed on the operating room table in the supine position with the head in the neutral position on a pillow and elevated ~10 cm. Standard monitors for general anaesthesia were applied, including ECG, blood pressure measurement, pulse oximetry, and capnography. Preoxygenation via medium-size plastic mask (Cardinal Health, Dublin, OH, USA) was carried out with a flow rate of 10 litre min^{-1} of 100% O_2 until the expired O_2 concentration reached ≥80%. The mask was connected to the breathing circuit (Cardinal Health) and used for preoxygenation and for mask ventilation for both mask ventilation techniques. An i.v. bolus injection of fentanyl (50–150 μg) was given before induction. Induction of anaesthesia was achieved by an i.v. bolus injection of propofol (1–2 mg kg^{-1}). Thereafter, based on the clinical assessment of the care team, an appropriate level of sedation was maintained with additional i.v. propofol.

When apnoea was observed, the subjects were ventilated with one of the two mask techniques in a randomized crossover manner. Ventilation began either with the C-E technique followed by the V-E technique (Group A) or with the reverse sequence, that is, V-E technique followed by C-E technique (Group B), as shown in Fig. 2. After induction, ventilation was obtained with the ventilator set to pressure-control mode at a rate of 10 bpm, inspiratory-to-expiratory time ratio (I:E) of 1:2, peak inspiratory pressure (PIP) of 20 cm H_2O, and no PEEP. Subjects started with one technique (Step 1) and crossed over to the other technique (Step 2), as shown in Fig. 2. The subjects in Group A were first ventilated with the C-E technique. If the subjects were adequately ventilated, as defined by perceivable chest movement and carbon dioxide measured during exhalation in at least one of the first three consecutive breaths, ventilation was continued until completion of 10 breaths, for 1 min (Step 1). Subjects were then ventilated with the V-E technique (Step 2). In Step 1, if ventilation failed with the C-E technique for all of the first three consecutive breaths, the subject was crossed over to the V-E technique (Step 2). If ventilation failed again with all of the first three consecutive breaths after crossover with the V-E technique, the study was terminated. Once Step 2 was completed, routine care was applied, including oral or nasal airway placement or placement of a laryngeal mask airway. If tracheal intubation was planned, a paralytic agent, either rocuronium or succinylcholine, was given, and the subject was intubated. Subjects in Group B followed the same protocol as that in Group A, except that the sequence of applying the two mask ventilation techniques was reversed, as shown in Fig. 2.

All ventilatory settings and measured parameters displayed on the operating room ventilator (Datex Ohmeda AS/5, Helsinki, Finland), including expired tidal volume (VTe), flow waveforms, end-tidal carbon dioxide partial pressure, exhaled carbon dioxide waveforms, and vital signs displayed on the monitor were preserved electronically. The target number for ventilation was 10 breaths for both C-E and V-E techniques. Only the last five breaths (only three breaths for failed ventilation) were used for final analysis to calculate the VTe and PIP. The mean of five breaths (three breaths if mask ventilation failed) was used as a single data point. Attempted mask ventilation was considered a failure if VTe≤anatomic dead space (in millilitres), which was calculated by predicted lean body weight (in kilograms) multiplied by 2.2 as described previously.[14]

Biostatistical analysis

The primary outcome was VTe, and secondary outcomes included VTe/actual weight, VTe/predicted body weight (PBW), and PIP. Student's paired *t*-test and McNemar's test were used to compare quantitative and categorical outcomes, respectively, with respect to mask ventilation technique. A sample size of 85 was determined to be sufficient to detect a 100 ml mean difference in VTe with 80% power, assuming an SD of 325 ml and a 5% type I error rate. The independent sample *t*-test and χ^2 test were used to compare baseline subject characteristics across the randomization groups A (C-E then V-E) and B (V-E then C-E). Data were analysed using Statistical Package for the Social Sciences (SPSS) 20.0 (IBM) (Armonk, NY, United States). Unless otherwise noted, data are presented as the mean (SD) or frequency (%). Statistical significance was defined as a two-sided *P*-value <0.05.

Results

A total of 103 subjects were enrolled. Twenty-two of them were excluded. The detailed information concerning exclusion is provided in Fig. 3. A total of 81 subjects underwent final analysis, and their characteristics are listed in Table 1. One subject in Group B had desaturation briefly during the C-E technique, with the lowest reading of pulse oximetry (Sp_{O_2}) of 89%. For this subject, the study was terminated and an oral airway inserted. The Sp_{O_2} value of this subject quickly reverted to >95%. All other subjects sustained Sp_{O_2} values >95% throughout the entire study period. There was no other adverse event observed in either group. There were no significant differences in haemodynamic parameters between the two groups during the study period.

A total of 63 operators provided mask ventilation for one to four subjects for a total of 81 instances of mask ventilation. The characteristics of the operators are listed in Table 1. There were no significant differences in the level of operator experience between the two groups. All 81 subjects achieved target peak

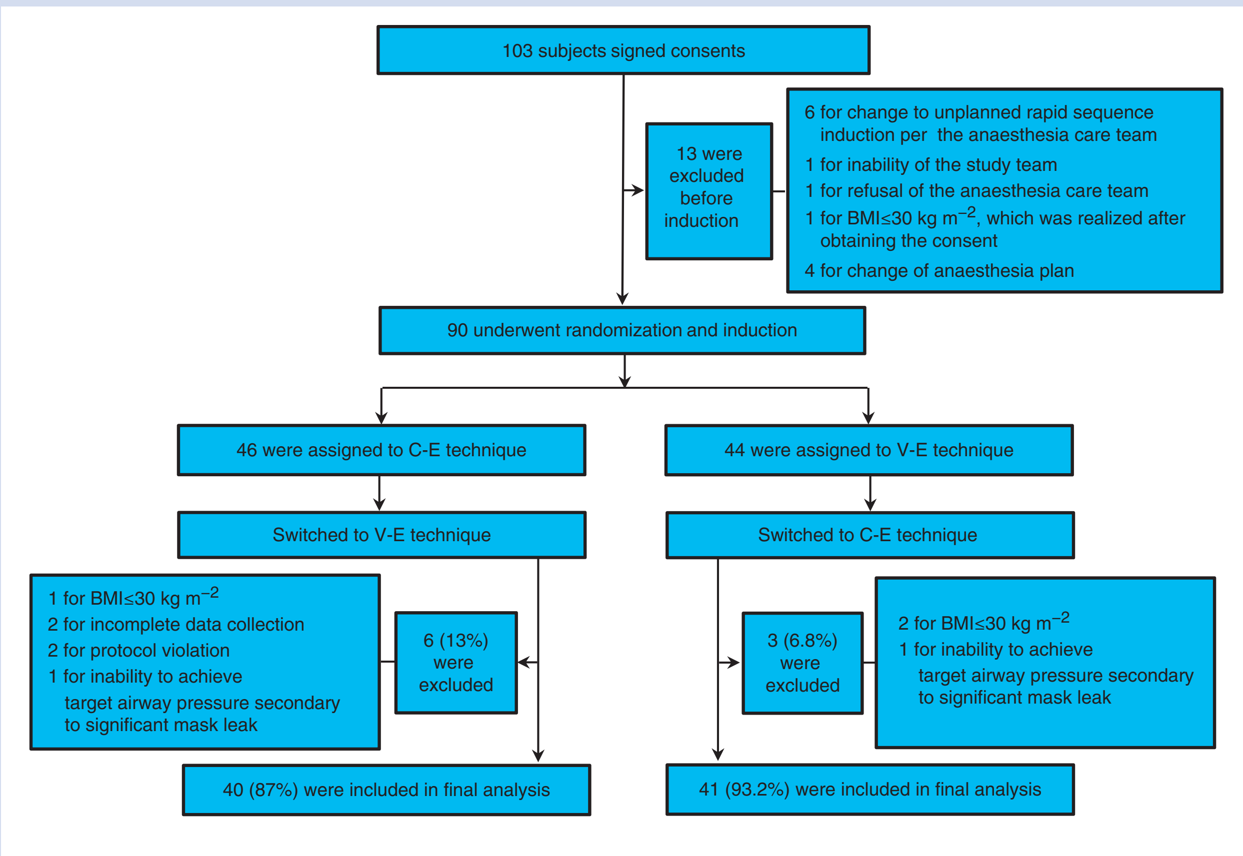

Fig 3 Subject enrolment and selection.

airway pressure. The PIP was 20.9 (SD 1.5) cm H_2O for the C-E technique and 20.6 (1.3) cm H_2O for the V-E technique ($P<0.001$), regardless of mask ventilation success (Table 2 and Fig. 4). Among subjects for whom C-E technique was successful (n=45), the PIP was 20.5 (1.3) cm H_2O for the C-E technique and 20.5 (1.3) cm H_2O for the V-E technique (P=0.741).

In Group A, 40 subjects started in Step 1 with the C-E technique, and 20 of them (50%) failed mask ventilation. All failed attempts at mask ventilation with the C-E technique were successfully rescued with the V-E technique in Step 2. In Group B, all 41 subjects starting with the V-E technique were effectively ventilated in Step 1, and 16 of these failed with the C-E technique in Step 2. Thirty-six of the 81 subjects (44.4%) failed mask ventilation with the C-E technique, and none failed with the V-E technique ($P<0.001$). All who failed mask ventilation with the C-E technique were ventilated effectively with V-E technique regardless of sequence.

Table 1 Characteristics of the subjects and operators. PBW, predicted body weight, which was calculated as PBW (in kilograms) for men=50+0.9[Height (in centimetres)−152.4], and for women=45.5+0.9[Height (in centimetres)−152.4]. Sixty-three operators provided mask ventilation for 81 subjects, because some of the operators participated in the study more than once

Characteristic	Group A	Group B
Subjects (n=81)		
Age [yr; mean (range)]	55 (24–77)	55 (29–80)
Sex		
Male	21	23
Female	19	18
ASA physical status		
I	1	0
II	12	13
III	27	28
Height [cm; mean (SD)]	174 (10.5)	175 (9.8)
Weight [kg; mean (SD)]	109 (21.2)	113 (17.7)
BMI [kg m^{-2}; mean (SD)]	36 (5.1)	37 (4.6)
PBW [kg; mean (SD)]	67 (10.8)	68 (10.7)
Operators		
Sex [n (%)]		
Male	19 (48)	16 (39)
Female	21 (53)	25 (61)
Level of experience [yr; n (%)]		
>5	1 (2.5)	2 (4.9)
3–5	9 (22.5)	9 (22.0)
1–2	30 (75.0)	30 (73.2)

For the 81 subjects, the VTe was 371 (SD 345) ml for the C-E technique and 720 (244) ml for the V-E technique ($P<0.001$), as shown in Table 2 and Fig. 4, regardless of mask ventilation failure. Among subjects for whom the C-E technique was successful (n=45), the mean VTe obtained using the C-E technique [633 (242) ml] was significantly smaller than that obtained with V-E technique [755 (245) ml; $P<0.001$; Fig. 4].

Discussion

The major findings from this study are as follows: (ii) using the two-handed mask ventilation method, the modified V-E technique was associated with a greater effectiveness of mask ventilation than the C-E technique, and all the subjects were effectively ventilated with the modified V-E technique; (ii) among those subjects who were effectively ventilated with both techniques, the modified V-E technique produced larger tidal volume than the C-E technique; and (iii) all subjects who failed mask ventilation with the C-E technique were effectively ventilated with the V-E technique. Our results demonstrate substantial improvement of mask ventilation in obese adults with the modified V-E technique compared with the C-E technique.

There are three components of the conventional V-E technique: (i) neck extension; (ii) lower jaw advance; and (iii) applying

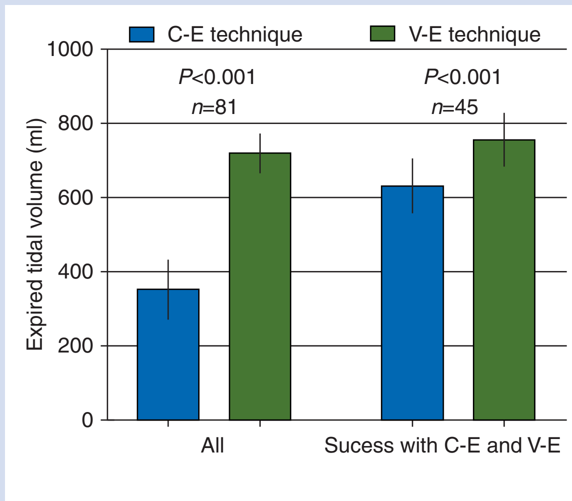

Fig 4 Expired tidal volume stratified by C-E and V-E technique, and by the full cohort (all, n=81) or the subset for which both C-E and V-E technique were successful (success, n=45).

Table 2 Efficiency of mask ventilation obtained with C-E vs V-E technique. Data are summarized using the mean (sd) [95% CI] or percentage [95% CI]. AW, actual weight; CI, confidence interval; PBW, predicted body weight; VTe, expired tidal volume. The P-values for C-E vs V-E comparisons, using either Student's paired t-test or McNemar's test, were all <0.001

Parameter	C-E technique	V-E technique	Difference
VTe (ml)	371 (345) [295, 447]	720 (244) [666, 773]	348 [274, 422]
VTe (ml kg^{-1}), AW	3.5 (3.49) [2.8, 4.3]	6.7 (2.6) [6.1, 7.3]	3.1 [2.5, 3.8]
VTe (ml kg^{-1}), PBW	5.9 (5.77) [4.6, 7.2]	10.9 (4.2) [10.0, 11.9]	5.1 [4.0, 6.1]
Ventilatory failure (%)	44 [34, 55]	0 [0, 5]	–

four fingers behind the angle of the mandible.[13] Our modified V-E technique has an additional component: keeping the mouth open. We believe that the improvement in mask ventilation with the modified V-E technique is supported by several factors. When an unconscious individual is in the supine position, the tongue falls posteriorly, as shown in a previous study,[15] and another study demonstrated that the velopharynx is the site causing upper airway obstruction.[16] Airway patency is improved with neck extension and lower jaw advancement.[17 18] Keeping the mouth open is a key component to produce effective mask ventilation.[19] Likewise, keeping the mouth open is also a key component for effective mouth-to-mouth breathing as demonstrated by Safar[20] nearly 60 yr ago. We did not compare the efficiency of mask ventilation using the conventional V-E technique that does not require mouth opening. However, during this study we observed that inability to keep the mouth open leads to difficult mask ventilation with the V-E technique.

The improvement in airway patency with the V-E technique may be attributable to the lack of compression on submandibular tissue resulting from the placement of the operator's fingers away from the front of the neck compared with the direct compression caused by the placement of the operator's fingers on the front of the neck that occurs with the C-E technique. This is well illustrated by Online video clip 1. With the modified V-E technique, the positive pressure generated by mask ventilation pushes submandibular tissue anteriorly. However, such movement is dramatically restricted with the C-E technique, as the counter-action of the operator's fingers pushes the submandibular tissues posteriorly. Essentially, it is the operator who makes the mask ventilation difficult with the C-E technique, rather the subject's innate anatomy. Another piece of supporting evidence is found in the high efficiency of continuous positive airway pressure (CPAP) devices used to treat patients with obstructive sleep apnoea (OSA).[21] In patients with OSA who use either a nasal mask or a full face mask to apply CPAP,[22] positive pressure keeps the upper airway patent. However, effective mask ventilation often proves difficult to achieve when these OSA patients are under anaesthesia.[23 24] One of the major differences in applying the mask is the lack of compression on submandibular tissue when straps are used for CPAP treatment of patients with OSA, compared with the C-E technique, where substantial external compression of pharyngeal tissues occurs.

In this study, we did not attempt to illustrate how the V-E technique is more effective than the C-E technique. Rather, we focused on whether the effectiveness of mask ventilation obtained with these two techniques is different. Given that the study was randomized and crossed over (each patient acting as their own comparator), the greater *V*Te obtained with the V-E technique is not likely to result from an increase in respiratory compliance, nor to be related to the higher PIP with V-E than that with the C-E technique. In fact, the PIP with C-E was slightly (1.4%) but statistically higher than with the V-E technique. Therefore, we believe that improvement in mask ventilation with the V-E technique occurs as a reduction in airway obstruction.

We intended to determine whether these two mask ventilation techniques are rescue methods for each other. In other words, when one technique fails, can the other rescue? We were unable to ventilate effectively 20 of the 40 subjects (50%) who began with the C-E technique. However, all 20 subjects who failed ventilation with the C-E technique were rescued effectively with the V-E technique. In contrast, all 41 subjects whose ventilation began with the V-E technique were effectively ventilated. Therefore, we did not have the opportunity to determine whether failed V-E mask ventilation could be rescued with the C-E technique. Sixteen of the 41 subjects (39%) were unable to be ventilated during subsequent ventilation with the C-E technique in Group B. These results indicate that subjects who are effectively ventilated with the V-E technique are not necessarily ventilated effectively with the C-E technique. All subjects who failed mask ventilation with the C-E technique were ventilated effectively with the V-E technique. Therefore, we believe that the C-E technique should not be attempted and the V-E technique should be the primary technique unless the V-E technique is not obtainable.

We believe this is the first demonstration of the superiority of the modified V-E technique in a well-controlled environment, with a randomized and crossover design. Although the study was in operating room settings, with unconsciousness induced by sedation, we believe that the superiority of the V-E technique to the C-E technique is likely to exist in comatose victims in emergency room settings or during field resuscitation. As there is a great deal of similarity in the mechanism of upper airway obstruction between comatose victims and anaesthetized individuals, the response to treatment, in this instance mask ventilation, should be similar. Of course, further study is needed to validate the observation in other populations.

There are several limitations to this study. First, we did not use an oral airway or a nasal airway during this study. It remains to be determined whether using an oral or a nasal airway would alter our findings. However, even without an oral or a nasal airway, the modified V-E technique produces effective mask ventilation [95% confidence interval (CI) for *V*Te 671–772 ml] with possible small ventilation failure rate (95% CI 0–5%), even the true observed failure rate was zero. Therefore, it is unlikely that insertion of an oral or a nasal airway would produce a higher efficiency of the C-E technique compared with modified V-E technique without insertion of an oral or a nasal airway.

Second, this study was conducted only on anaesthetized subjects. The mechanism of airway obstruction in anaesthetized subjects is similar, but may not be identical, to that of comatose subjects. Whether the superiority of the modified V-E technique to the C-E technique observed in anaesthetized subjects is reproducible in comatose individuals remains to be determined.

Third, we conducted this study on obese subjects only. Given that obesity is a well-known contributing factor to difficult mask ventilation,[21 24] the superiority of the V-E technique to the C-E technique might be overestimated compared with results obtained in a study of a less obese population. In addition, the mechanism of difficult mask ventilation may be different in the obese compared with the non-obese. Nevertheless, it seems unlikely that the V-E technique is inferior to the C-E technique in those who are difficult to ventilate with a mask or even in those who are not difficult to ventilate with a mask. In short, the modified V-E technique is likely to be at least equal to, if not better than, the C-E technique in other populations.

Fourth, the modified V-E technique is not commonly used, and it seems to need more effort for the provider to apply the mask correctly than C-E technique. The learning curve of this technique remains to be determined.

Finally, the study was not blinded. The operators were aware of the purpose of the study. However, we chose pressure-mode ventilation, and the ventilation settings were constant during mask ventilation with each technique. In addition, tidal volume was automatically recorded, and the ventilator parameters were videotaped and analysed. It is unlikely that the difference between tidal volumes obtained with the two techniques was attributable to effects of the experimental procedure. Rather, it is more likely that the difference between tidal volumes obtained with the two techniques was the result of a primary difference in airway patency attributable to the modified V-E technique itself. We observed that there was statistically a difference in PIP between the two techniques. The PIP during ventilation with the C-E technique was modestly higher, by 1.5%, than that with the V-E technique (20.9 *vs* 20.6 cm H_2O). Although the PIP during mask ventilation with the C-E technique was higher than that with the V-E technique, the *V*Te obtained with the C-E technique was smaller than that obtained with the V-E technique. It is unlikely that the smaller *V*Te with the C-E technique was attributable to the operators' attempts to create intentionally inadequate mask seals and subsequent mask leaks. Rather, it is likely to be the result of a greater degree of airway obstruction during mask ventilation with the C-E technique than with the V-E technique.

In summary, the modified V-E technique for mask ventilation is more effective than the C-E technique. Given that two-handed mask ventilation is the last option as a rescue measure if the return of spontaneous breathing and tracheal intubation are impossible, the modified V-E, not the C-E, technique should be attempted first. This finding potentially applies to other rescue situations.

Authors' contributions

Study design: M.F., J.L.B., M.J.R., D.A.E., Y.L., M.A.P., M.S.S., Y.J.
Institutional Review Board application: M.F., M.J.R., Y.L., M.A.P., M.S.S., Y.J.
Patient enrolment: M.F., J.L.B., Y.J.
Data collection: M.F., J.L.B., M.J.R., D.A.E., M.A.P., M.S.S., Y.J.
Data analysis: M.F., J.L.B., M.J.R., D.A.E., Y.L., M.S.S., Y.J.
Manuscript preparation: M.F., J.L.B., M.J.R., D.A.E., Y.L., M.A.P., M.S.S., Y.J.

Online video

The video associated with this article can be viewed from the article in *British Journal of Anaesthesia* online.

Declaration of interest

None declared.

References

1. Kheterpal S, Martin L, Shanks AM, Tremper KK. Prediction and outcomes of impossible mask ventilation: a review of 50,000 anesthetics. *Anesthesiology* 2009; **110**: 891–7
2. Langeron O, Masso E, Huraux C, *et al*. Prediction of difficult mask ventilation. *Anesthesiology* 2000; **92**: 1229–36
3. Adnet F. Difficult mask ventilation: an underestimated aspect of the problem of the difficult airway? *Anesthesiology* 2000; **92**: 1217–8
4. Shiga T, Wajima Z, Inoue T, Sakamoto A. Predicting difficult intubation in apparently normal patients: a meta-analysis of bedside screening test performance. *Anesthesiology* 2005; **103**: 429–37
5. European Resuscitation Council. European Resuscitation Council guidelines for resuscitation 2005. *Resuscitation* 2005; **67**: S1–189
6. Yentis SM. Predicting trouble in airway management. *Anesthesiology* 2006; **105**: 871–2
7. Wang HE, Mann NC, Mears G, Jacobson K, Yealy DM. Out-of-hospital airway management in the United States. *Resuscitation* 2011; **82**: 378–85
8. Hubble MW, Brown L, Wilfong DA, Hertelendy A, Benner RW, Richards MEA. Meta-analysis of prehospital airway control techniques. Part I: orotracheal and nasotracheal intubation success rates. *Prehosp Emerg Care* 2010; **14**: 377–401
9. Hart D, Reardon R, Ward C, Miner J. Face mask ventilation: a comparison of three techniques. *J Emerg Med* 2013; **44**: 1028–33
10. Gerstein NS, Carey MC, Braude DA, *et al*. Efficacy of facemask ventilation techniques in novice providers. *J Clin Anesth* 2013; **25**: 193–7
11. Joffe AM, Hetzel S, Liew EC. A two-handed jaw-thrust technique is superior to the one-handed "EC-clamp" technique for mask ventilation in the apneic unconscious person. *Anesthesiology* 2010; **113**: 873–9
12. Davidovic L, LaCovey D, Pitetti RD. Comparison of 1- versus 2-person bag-valve-mask techniques for manikin ventilation of infants and children. *Ann Emerg Med* 2005; **46**: 37–42
13. Saddawi-Konefka D, Hung SL, Kacmarek RM, Jiang Y. Optimizing mask ventilation: literature review and development of a conceptual framework. *Respir Care* 2015; **60**: 1834–40
14. Numa AH, Newth CJ. Anatomic dead space in infants and children. *J Appl Physiol* 1996; **80**: 1485–9
15. Kuna ST, Woodson LC, Solanki DR, Esch O, Frantz DE, Mathru M. Effect of progressive mandibular advancement on pharyngeal airway size in anesthetized adults. *Anesthesiology* 2008; **109**: 605–12
16. Hillman DR, Platt PR, Eastwood PR. The upper airway during anaesthesia. *Br J Anaesth* 2003; **91**: 31–9
17. Safar P, Escarraga LA, Chang F. Upper airway obstruction in the unconscious patient. *J Appl Physiol* 1959; **14**: 760–4
18. Matioc AA. The adult ergonomic face mask concept: historical and theoretical perspectives. *J Clin Anesth* 2009; **21**: 300–4
19. Sato Y, Ikeda A, Ishikawa T, Isono S. How can we improve mask ventilation in patients with obstructive sleep apnea during anesthesia induction? *J Anesth* 2013; **27**: 152–6
20. Safar P. Ventilatory efficacy of mouth-to-mouth artificial respiration: airway obstruction during manual mouth-to-mouth artificial respiration. *JAMA* 1958; **167**: 335–41
21. Kushida CA, Littner MR, Hirshkowitz M, *et al*.; American Academy of Sleep Medicine. Practice parameters for the use of continuous and bilevel positive airway pressure devices to treat adult patients with sleep-related breathing disorders. *Sleep* 2006; **29**: 375–80
22. Sullivan CE, Issa FG, Berthon-Jones M, Eves L. Reversal of obstructive sleep apnoea by continuous positive airway pressure applied through the nares. *Lancet* 1981; **1**: 862–5
23. Leoni A, Arlati S, Ghisi D, *et al*. Difficult mask ventilation in obese patients: analysis of predictive factors. *Minerva Anestesiol* 2014; **80**: 149–57
24. Walls RM, Brown CA III, Bair AE, Pallin DJ; NEAR II Investigators. Emergency airway management: a multicenter report of 8937 emergency department intubations. *J Emerg Med* 2011; **41**: 347–5

Handling editor: Takashi Asai