Efficacy of facemask ventilation techniques in novice providers

Neal Stuart Gerstein MD (Associate Professor) a,⁎, Michael Christopher Carey MD (Assistant Professor) a, Darren Alan Braude MD (Professor) a,b, Isaac Tawil MD, FCCM (Assistant Professor) a,b, Timothy Randal Petersen PhD (Research Coordinator, Adjunct Assistant Professor) a,c, Lev Deriy MD (Assistant Professor) a, Mark Spencer Anderson BA (Medical Student) d

a Department of Anesthesiology and Critical Care Medicine, University of New Mexico School of Medicine, Albuquerque, NM 87131, USA
b Department of Emergency Medicine, University of New Mexico School of Medicine, Albuquerque, NM 87131, USA
c Department of Anthropology, University of New Mexico, Albuquerque, NM 87131, USA
d University of New Mexico School of Medicine, Albuquerque, NM 87131, USA

Original Contribution

Study Objective: To determine which of two facemask grip techniques for two-person facemask ventilation was more effective in novice clinicians, the traditional E-C clamp (EC) grip or a thenar eminence (TE) technique.

Design: Prospective, randomized, crossover comparison study.

Setting: Operating room of a university hospital.

Subjects: 60 novice clinicians (medical and paramedic students).

Measurements: Subjects were assigned to perform, in a random order, each of the two mask-grip techniques on consenting ASA physical status 1, 2, and 3 patients undergoing elective general anesthesia while the ventilator delivered a fixed 500 mL tidal volume (VT). In a crossover manner, subjects performed each facemask ventilation technique (EC and TE) for one minute (12 breaths/min). The primary outcome was the mean expired VT compared between techniques. As a secondary outcome, we examined mean peak inspiratory pressure (PIP).

Main Results: The TE grip provided greater expired VT (379 mL vs 269 mL), with a mean difference of 110 mL (P = 0.0001; 95% CI: 65, 157). Using the EC grip first had an average VT improvement of 200 mL after crossover to the TE grip (95% CI: 134, 267). When the TE grip was used first, mean VTs were greater than for EC by 24 mL (95% CI: -25, 74). When considering only the first 12 breaths delivered (prior to crossover), the TE grip resulted in mean VTs of 339 mL vs 221 mL for the EC grip (P = 0.0128; 95% CI: 26, 209). There was no significant difference in PIP values using the two grips: the TE mean (SD) was 14.2 (7.0) cm H2O, and the EC mean (SD) was 13.5 (9.0) cm H2O (P = 0.49).

Conclusions: The TE facemask ventilation grip results in improved ventilation over the EC grip in the hands of novice providers.

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⁎⁎⁎ Corresponding author. Department of Anesthesiology and Critical Medicine, University of New Mexico School of Medicine, MSC 11 6129, 1 University of New Mexico, Albuquerque, NM 87131, USA. Tel.: +1 505 272 2610; fax: +1 505 272 1300. E-mail address: ngerstein@gmail.com (N.S. Gerstein).

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1. Introduction

Bag-valve mask ventilation (BMV) is a critical airway skill for managing both in-hospital and out-of-hospital emergencies. Providers with limited airway experience manage many of these cases, yet it is widely recognized that BMV is difficult for novices [1].

Bag-valve mask ventilation may be performed using either a one-person or two-person technique. The two-person technique is more effective for novices [2–5]. The two-person BMV technique is also recommended for experienced providers when facemask ventilation is difficult. Many sources, including the American Heart Association (AHA) and the New England Journal of Medicine Videos in Clinical Medicine, advocate the “E-C clamp” (EC) grip for holding the mask to the face when performing two-person BMV [6,7] (Fig. 1). This grip has been termed the “E-C clamp” because the thumb and index finger form the shape of a “C” around the mask, with the other three fingers forming the letter “E” on the inferior portion of the mandible. An alternative mask seal technique for two-person BMV, recommended by some sources, is the “thenar eminence” (TE) grip, in which...
downward pressure is applied with the thenar eminences while the 4 fingers of each hand pull the jaw upwards toward the mask [8,9] (Fig. 2).

In our experience, the TE grip is easier for novices than the EC grip. However, these two techniques have not been subjected to a rigorous clinical comparison outside of a single abstract. We hypothesized that novice providers (ie, medical and paramedic students) using both approaches for simulated two-person facemask ventilation in a controlled setting would be more successful in ventilation using the TE technique than the EC grip.

2. Materials and methods

The protocol was approved by the Human Research Review Committee at the University of New Mexico Health Science Center. Patients provided written, informed consent to participate in the study separately from the consent given for their surgical procedure. This study compared the efficacy between two different two-handed facemask ventilation techniques: the EC and TE grips, during ventilation of unconscious, apnoic patients by novice providers. Patients included in the study were adults over age 18 years, presenting for elective surgery requiring general anesthesia. Exclusion criteria included emergency surgery, expected difficult endotracheal intubation or supraglottic airway insertion, full stomach, or the need for rapid-sequence intubation for any reason. Patient information collected included age, gender, ASA physical status, height, weight, and body mass index (BMI).

Study subjects were University of New Mexico School of Medicine medical students or New Mexico Emergency Medicine Academy students (paramedic students) in good standing. These subjects were recruited by email or during clinical education activities in the hospital operating room (OR). Subjects’ previous experience ranged from no airway management experience to only limited experience. Participating subjects provided verbal consent to participate in the study. Before the start of the study protocol, subjects watched a standardized 60-second video that demonstrated each technique once.

Subjects were randomly assigned to an odd or even number to determine which technique would be performed first. Odd-numbered subjects started with the TE technique and even-numbered subjects started with the EC technique. Hence, half the subjects were assigned to perform the EC technique first (12 breaths), followed by 12 breaths of the TE technique. The other half began with the TE technique, followed by the EC technique.

Patients were brought to the OR after consent. In each OR, an anesthesiologist not participating in the study was assigned to manage the anesthesia for the case. In addition, a study investigator not providing anesthesia was present to record data and to monitor adherence to the study protocol. Patients were premedicated with 1–2 mg of midazolam. Pulse oximetry, electrocardiogram, and noninvasive blood pressure monitors were placed, followed by preoxygenation/denitrogenation with 100% O$_2$ for three minutes. General anesthesia was induced with 2–3 mg/kg of propofol, 1.5 mg/kg of lidocaine, and 1–3 μg/kg of fentanyl. No neuromuscular blocking agents were administered. After induction and apnea confirmation, an oropharyngeal airway adjunct was placed, and subjects began the protocol. One of two types of anesthesia machines was used: the Dräger Apollo or Fabius-GS (Dräger Medical Inc., Telford, PA, USA). The anesthesia machine was preset in volume-controlled mode to deliver 12 breaths/min, 500 mL Vt, an inspiratory flow rate of 10 L/min, with no additional positive end-expiratory pressure. A Dynjama-mask size 7 anesthesia mask was used during the study (Medline Industries Inc., Mundelein, IL, USA).

Subjects were instructed to start with either the EC or TE technique as assigned once apnea and loss of consciousness were confirmed. Each volunteer performed each technique for 60 seconds (12 breath cycles). Between techniques, subjects had a 10–20 second rest, during which time an anesthesiologist not involved in the study ventilated the patient. The investigator recorded all data manually from the anesthesia machine's ventilator readout. Recorded data included expired Vt and peak inspiratory pressure (PIP) for each breath. If a patient had a significant oxygen saturation (SpO$_2$) decrease or hemodynamic instability deemed significant by the non-study anesthesiologist, the protocol was aborted, the non-study anesthesiologist assumed patient management, and in these cases, data of zero were entered for the remaining breaths. In such cases, appropriate patient safety measures were taken and the patient's anesthesia and surgery proceeded normally.

We elected to perform an intention-to-treat analysis rather than a per-protocol analysis. We also chose to include zero-volume breaths because that best accounts for the clinically significant inability to deliver at least some of the 12 breaths.

All statistical analyses were performed with JMP software (version 9.0.0; SAS Institute Inc., Cary, NC, USA). The primary outcomes in this
study were the 12-breath mean expired $V_T$ compared between grip techniques without accounting for sequence of application. As secondary outcomes, we examined mean PIP and whether a technique sequence produced a learning effect in either $V_T$ or PIP. To evaluate for a possible learning effect, we compared subjects’ 12-breath $V_T$ and PIP means on their first attempts and examined whether ventilation failures (expired $V_T$ of zero) were equally distributed between the grip techniques. Because this was a study of the difference between techniques, each study subject/patient pair acted as their own control for all comparisons except the first attempt and ventilation failure analyses. We used paired t-tests to evaluate our hypotheses for the primary outcome and the learning effect issue, a standard t-test for the first-attempt analysis, and chi-square to evaluate ventilation failures’ distribution. To calculate the sample size needed for a paired t-test comparing individual subjects’ performance with the EC and TE grips, we assumed mean (SD) $V_T$s near 450 (60) mL. We chose 80% power to detect a between-grips difference of 22.5 mL (approx 5% of a typical $V_T$) at two-tailed α = 0.05. With JMP statistical software, these parameters yielded an estimated sample size of 58 participants, which we rounded up to 60 participants (yielding power of 81.5%).

### 3. Results

A total of 60 subjects and 60 patient participants were recruited between January and March of 2011. Thirty subjects were randomly assigned to begin with the EC grip and 30 subjects, with the TE grips. Data were available for 59 subject pairs (98%) and were used in the final analysis. One patient was withdrawn from the study due to machine failure; the machine was replaced and the subject’s surgery proceeded uneventfully. The analysis below includes 4 subjects who proceeded uneventfully. The analysis below includes 4 subjects who were unable to achieve a measurable $V_T$ using either grip and three who were successful with one grip (TE) but unable to achieve any measurable volumes with the other (EC). The attending physician intervened to restore effective ventilation in three of these cases when patient SpO2 decreased significantly (< 90%); data for these subjects were entered as zero for the remaining breaths. The subject associated with the machine failure mentioned above was in the EC-first group, thus 30 subject/patient pairs (51%) began with the TE grip and 29 (49%) with the EC grip. The results of this modified intention-to-treat analysis were consistent with a per-protocol analysis of data limited to study participants who were able to complete 24 breaths without desaturation. Therefore, while the decision to include volumes of zero in these comparisons reflects the realistic clinical practice experience of these novice providers, it is not solely responsible for the perceived effect.

Demographic data were captured for 58 of the 59 patient participants and evaluated for differences between the two randomized allocations (EC-TE vs TE-EC sequence). Overall, the two groups were similar in age, gender, ASA physical status, height, weight, and BMI, with no statistically significant differences with t-tests or chi-square analyses (Table 1).

The mean (SD) $V_T$ of all 24 recorded breaths delivered by those randomized to the TE-EC sequence versus the EC-TE sequence were 326 (186) mL and 321 (138) mL, respectively ($P = 0.91$, 95% CI for the difference: -90, 80 mL), demonstrating overall BMV skill equivalence among the two groups of novice study subjects.

As each patient-subject pair served as its own control, we used a pairwise analysis to compare overall ventilation success. The TE grip provided greater expired $V_T$ (379 mL vs 269 mL) with a mean difference of 110 mL ($P < 0.0001$; 95% CI for the difference: 65, 157 mL). Thus each subject achieved, on average, an additional 110 mL of $V_T$ by using the TE grip (a 41% increase over the EC grip $V_T$s; Fig. 3).

Subjects randomized to use the EC grip first realized an average improvement in the delivered $V_T$ of 200 mL after crossover to the TE grip (95% CI: 134, 267 mL). When the TE grip was used first, mean $V_T$ was still larger than for EC, but only by 24 mL (95% CI: -25, 74 mL). This sequence effect is significant; $P$-test, $P = 0.0001$ (Fig. 4).

When considering only the first 12 breaths delivered by the novice providers (prior to crossover; see the dark gray bars in Fig. 4), the TE grip resulted in a mean (SD) delivered $V_T$ of 339 (180) mL versus 221 (170) mL for the EC grip. This represents an average $V_T$ difference of 118 mL (53% greater) using TE versus EC grip among first-time facemask ventilation providers; ($P = 0.0128$; 95% CI: 26, 209 mL).

A similar pairwise analysis was used to compare PIP. No significant difference was noted between pressures obtained using the two-grip techniques: the mean (SD) was 14.2 (7.0) cm H2O and the EC mean (SD) was 13.5 (9.0) cm H2O ($P = 0.49$; 95% CI: -1.26, 2.59 cm H2O; Fig. 5). There was no corresponding sequence effect for PIP ($P = 0.44$). As for comparison of subjects assigned to one group or the other, no significant differences were noted between the two subject groups’ achieved PIP over all 24 breaths ($P = 0.60$). Subjects did not have significantly different PIP values on their first ventilation attempts (first 12 breaths; $P = 0.89$).

Sixteen study subjects had at least one ventilation failure during one of their 24 consecutive breaths. Ten of these subjects’ ventilation failures were using the EC grip alone, 5 subjects registered failed ventilations during both EC and TE grips, and one failed exclusively

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### Table 1

Characteristics of study patients

<table>
<thead>
<tr>
<th></th>
<th>Ventilation sequence</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>EC - TE (n=29)¹</td>
<td>TE - EC (n=28)³</td>
</tr>
<tr>
<td>Means (SD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>46.6 (15.7)</td>
<td>49.6 (13.5)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.1 (12.0)</td>
<td>166.9 (10.4)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>82.9 (17.7)</td>
<td>77.9 (17.8)</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>29.4 (5.9)</td>
<td>27.9 (6.1)</td>
</tr>
<tr>
<td>Gender (M/F) (n/%)</td>
<td>14/14 (50/50)</td>
<td>16/12 (57/43)</td>
</tr>
<tr>
<td>ASA physical status (1,2,3) (n/%)</td>
<td>6/17/5 (21/61/18)</td>
<td>4/18/0 (14/64/21)</td>
</tr>
</tbody>
</table>

¹ means normal healthy patient, 2=patient with mild systemic disease, 3=patient with severe systemic disease. ASA physical status 4 patients (ie, having severe systemic disease that is a constant threat to life) or higher were not enrolled.

² EC = subject group who started with the traditional E-C clamp (EC) grip, then changed to a thenar eminence (TE) technique; TE = EC=subject group who began with the TE technique, then changed to the EC grip technique.

³ Demographic data were inadvertently omitted from one EC - TE patient’s data sheet.

⁴ ASA physical status categories.

⁵ Percentages do not sum to 100 due to rounding.
ventilation is also occasionally difficult for experienced providers; it is estimated that the incidence of difficult mask ventilation can be as high as 15% [11]. Thus, there remains room for improvement, yet there have been few major developments since the work by Safar et al over 50 years ago [12].

The TE technique is superior to the EC technique when novices perform two-handed facemask ventilation on anesthetized apneic patients. Currently, BLS, ACLS, and PALS teach BMV with the EC facemask technique [6]. As difficult mask ventilation is common, a simple modification in the way one holds the mask against the face may improve ventilation efficacy.

There are a number of ways in which to determine the relative efficacy of facemask ventilation. The goal is to provide adequate ventilation and oxygenation. To determine the efficacy of ventilation with facemask ventilation, we examined the primary outcome of VT as reflected by the volume of exhaled gases as compared to a set inspiratory VT. As part of our secondary outcome analysis, the number of failed breaths as reflected by no exhaled volumes recorded by the anesthesia machine was examined. The difference between inspired and expired VT was selected as our primary outcome based on previous studies that showed that this measurement is a robust measure of the actual volume delivered [13,14]. Moreover, a recent study by Joffe et al [5] comparing the one-handed EC technique versus a two-handed jaw thrust technique also used mean expired VTs as outcome measurements. This group explicitly stated that one of the primary means by which to measure the adequacy of ventilation is assessment of exhaled gas volumes. Given that patients were all adequately preoxygenated prior to induction of anesthesia, we did not evaluate oxygenation as a marker of efficacy. In fact, if any patients significantly desaturated during the study period, the supervising anesthesiologist was instructed to intervene.

This study specifically compared the EC grip with the TE grip for patients who were apneic after induction of anesthesia. We found that, on average, the TE grip delivered greater expired VT (393±172 mL vs 269 ± 197 mL, P < 0.0001 for pairwise t-test) than the EC grip. This finding represented an additional 110 mL with each breath, or a 41% increase over the EC grip.

Data analysis also showed an interesting “sequence effect”, which also supports the TE grip as the more efficacious technique. When subjects were randomized to use the EC grip first, they realized an average improvement in delivered VT of 200 mL after crossover to the TE grip. However, when the TE grip was used first, mean VTs were only 24 mL larger with TE than what was recorded for the EC grip. We consider this finding to be important because it suggests that when novice providers change from the EC grip to the TE grip there is a marked improvement. When one changes from the TE to the EC grip, there is very little improvement. This finding may suggest that novice providers are better able to perform the EC technique if they have first learned ventilation fundamentals with the TE grip.

A possible explanation for this sequence effect is that the TE grip is superior. When one used the TE grip first, he or she was more likely to learn how a good VT “feels” and then more likely to apply good technique with the EC grip.

To minimize this sequence effect, we analyzed the average VT delivered for the first 12 breaths (prior to crossover). The 29 subjects who were randomized to the EC group first delivered, on average, 221.2 mL. The 30 subjects randomized to the TE group first delivered 338.5 mL. This represents an average VT improvement of 53% when the TE grip was used first by novice providers. The importance of this finding cannot be overstated because it suggests that for novices, the superior TE grip should be the default technique when performing two-handed facemask ventilation. Only as experience with facemask ventilation increases should one move to the EC grip to allow for one-handed facemask ventilation.

As another measure of ventilation efficacy, we analyzed the frequency of failed breaths between the two groups. We defined a
“failed breath” as a breath in which there was no measurable exhaled volume. After exclusion of the 4 subjects with complete ventilation failure using both grips, 16 study subjects did not achieve a measurable \( V_T \) on at least one of the 24 delivered breaths. Of these, 10 ventilation failures were using the EC grip alone, 5 registered failed ventilation using both grips, but only one failure occurred during the TE grip exclusively. It is unclear why 4 subjects were unable to ventilate with either technique. This may have been due to a significant lack of manual dexterity or smaller hand-size on the subject’s part, which may have been exacerbated by patient factors known to render BMV difficult (ie, edentulism, obesity, facial hair); unfortunately we did not record any of these variables.

There are a number of reasons as to why the TE technique may be superior to the EC technique for two-handed facemask ventilation. For effective facemask ventilation, it is important to advance the mandible anteriorly, thereby lifting the pharyngeal structures and relieving potential obstruction. With the EC technique, most of this upward force is generated with the 5th finger at the angle of the jaw. Alternatively, the 4 fingers of each hand are used to lift the jaw with the TE technique while the thenar eminences hold the mask against the face. Though not assessed objectively, a majority of subjects informally reported that far less effort was required to maintain the TE technique while the thenar eminences hold the mask against the face. Although not measured subjectively, majority of subjects noted that the TE technique was easier to learn for novices.

Interestingly, the PIP values recorded for the two techniques did not differ, regardless of the sequence. We do not have an obvious explanation for this. One might posit that if greater \( V_T \) were delivered with one technique, one would see a higher PIP. Alternatively, it is likely that the greater \( V_T \)s with the TE technique were due to maintaining a more patent airway so that these volumes were delivered with less relative airway pressures. Another possibility is that subjects held the mask against the patient’s face with a relatively constant pressure, regardless of which technique was used. With the EC technique, there is likely greater upper airway obstruction leading to greater leak around the mask and less volume delivered to the lungs, resulting in smaller \( V_T \) and variable airway pressures. The TE technique is less obstructive; thus, greater \( V_T \) is delivered although air still leaks from around the mask. In a simulated neonatal lung model, Bassani et al [15] showed significant variability in airway pressures (2.5 - 106.3 cm H2O) with various mask grip techniques. However, in the Bassani et al study there was a direct correlation between increasing \( V_T \) and airway pressure; in our study, in which there was no correlation. It is possible that our study was underpowered to detect differences in airway pressure between the EC and TE techniques. The important clinical point is that the TE grip delivered greater \( V_T \) without a demonstrable difference in airway pressures.

It deserves mention that one-person BMV can be performed only with the EC mask grip. If, as our findings suggest, two-person BMV were taught to novices with the facemask TE grip, they would need to learn two different mask grip techniques: the TE grip for two-person BMV and the EC grip for one-person BMV. This has its obvious drawbacks.

There are various limitations to our study. One limitation was the inability to extrapolate this experience, in a controlled anesthesia environment, to that of lay rescuers or emergency medical service (EMS) providers in the emergency setting. It is possible that the results would be different using a self-inflating bag in uncontrolled environments with nonanesthetized patients. There also may be a substantial difference depending on hand size. Anecdotally, those providers with smaller hands saw more benefit from the TE technique than did those with larger hands. We have also noticed that the shape of the mask also makes a difference. While this study was performed with a standard anesthesia mask, there is great variation among the masks used outside of the OR with self-inflating bags. Some of these masks are more comfortable with the EC grip than TE and vice versa.

In addition, if we were to repeat this study, we would consider using a pressure-controlled ventilation mode rather than volume-controlled ventilation to minimize the risk of gastric insufflation. Moreover, pressure-controlled ventilation permits standardization of airway pressure and inspiratory flow, and delivered \( V_T \) than is best reflected by changes in airway resistance [5]. Also, since we specifically looked at two minutes of ventilation, we cannot definitively comment on how each grip would perform over a longer period of time.

4.1. Conclusions

In summary, novices generated substantially greater \( V_T \)'s and fewer failed breaths when using the TE grip than the EC technique for two-handed facemask ventilation of anesthetized, adult apneic patients. These markers suggest superiority of the TE grip for two-handed facemask ventilation. In the interim, given the importance of BMV, we believe the TE technique should at least be taught as an option when ventilation with the EC technique is difficult. At our institution, we now teach novice trainees the TE as the preferred technique for two-person BMV.

References