

A Two-handed Jaw-thrust Technique Is Superior to the One-handed “EC-clamp” Technique for Mask Ventilation in the Apneic Unconscious Person

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ABSTRACT

Background: Mask ventilation is considered a “basic” skill for airway management. A one-handed “EC-clamp” technique is most often used after induction of anesthesia with a two-handed jaw-thrust technique reserved for difficult cases. Our aim was to directly compare both techniques with the primary outcome of air exchange in the lungs.

Methods: Forty-two elective surgical patients were mask-ventilated after induction of anesthesia by using a one-handed “EC-clamp” technique and a two-handed jaw-thrust technique during pressure-control ventilation in randomized, crossover fashion. When unresponsive to a jaw thrust, expired tidal volumes were recorded from the expiratory limb of the anesthesia machine each for five consecutive breaths. Inadequate mask ventilation and dead-space ventilation were defined as an average tidal volume less than 4 ml/kg predicted body weight or less than 150 ml/breath, respectively. Differences in minute ventilation and tidal volume between techniques were assessed with the use of a mixed-effects model.

Results: Patients were (mean \pm SD) 56 \pm 18 yr old with a body mass index of 30 \pm 7.1 kg/m². Minute ventilation was 6.32 \pm 3.24 l/min with one hand and 7.95 \pm 2.70 l/min with two hands. The tidal volume was 6.80 \pm 3.10 ml/kg predicted body weight with one hand and 8.60 \pm 2.31 ml/kg predicted body weight with two hands. Improvement with

two hands was independent of the order used. Inadequate or dead-space ventilation occurred more frequently during use of the one-handed compared with the two-handed technique (14 *vs.* 5%; *P* = 0.013).

Conclusion: A two-handed jaw-thrust mask technique improves upper airway patency as measured by greater tidal volumes during pressure-controlled ventilation than a one-handed “EC-clamp” technique in the unconscious apneic person.

What We Already Know about This Topic

- ❖ No study has systematically compared ventilatory effectiveness between one-handed and two-handed mask-hold techniques.

What This Article Tells Us That Is New

- ❖ Two-handed mask ventilation achieved greater tidal volume during pressure-controlled ventilation than one-handed mask ventilation in anesthetized, nonparalyzed patients with oropharyngeal airway inserted.

PROVISION of artificial ventilation to the unconscious and apneic patient *via* a mask applied to the patient's face is the most “basic” of airway management skills. Nonetheless, bag-valve mask ventilation is not always easy. Upper airway obstruction may be encountered at the level of the nares, soft palate, lips (when the mouth is closed), base of the tongue, tonsillar pillars, epiglottis, or even vocal cord inlet. To generate and maintain upper airway patency during artificial breathing, performance of the “triple airway maneuver” is advocated. This includes advancing the mandible forward until the lower teeth are in front of the upper teeth (jaw thrust), lifting the chin and maximally tilting the head backwards (chin lift, head tilt), and maintaining the mouth in an open position. As originally described, these airway maneuvers were performed with the operator positioned behind and at the head of the patient and using two hands.^{1,2} Placement of both hands on the mask, however, necessitates a second operator to squeeze the bag, which may be impractical if performed routinely.

As an alternative to the two-operator approach, pressure-controlled ventilation (PCV) can be applied by most modern

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anesthesia machines, allowing the operator to focus their attention on positioning the airway and the seal of the face-mask. Practitioners may be reluctant to use positive-pressure mechanical ventilation over concern for excessive peak airway pressures leading to gastric insufflation, regurgitation, and pulmonary aspiration or the inability to manually assess the patient's airway compliance and control tidal volumes with the breathing bag using their expertise. Neither of these concerns is well founded in the literature.^{3–6} When peak inspiratory pressures are titrated to achieve tidal volumes up to 10 ml/kg, PCV results in lower peak inspiratory flow and pressure compared with manual circle system ventilation with the use of an airway pressure release valve. So long as peak airway pressures are 15 cm H₂O or less, gastric insufflation does not occur.^{5,6} In addition, use of PCV rather than standard manual circle system ventilation in experimental models of mask ventilation provides standardization of airway flow, pressure, and inflation time, allowing changes in the tidal volume to reflect changes in airways resistance, particularly that in the upper airways.

Thus, the basis for performing bag-valve mask ventilation with a single hand, as is most commonly done, is a practical one. However, the generic left-hand grip with the fifth finger at the left mandibular angle and the third and fourth finger on the left mandibular ramus—the so-called “EC-clamp” technique—has been neither demonstrated in itself to generate or maintain a “triple airway maneuver” nor compared with a two-handed mask hold technique.⁷ The primary aim of our study was to compare maintenance of upper airway patency during mask ventilation assessed by the tidal volume during the PCV between one hand and two hands mask ventilation techniques.

Materials and Methods

The University of Wisconsin Health Sciences Institutional Review Board (Madison, Wisconsin) approved this prospective, randomized, open-label, crossover study. This study took place between September 1 and October 15, 2009. Eligible were all patients 18 yrs and older who were scheduled for elective surgery with general anesthesia and the placement of an endotracheal tube. Patients receiving etomidate (Amidate®; Hospira, Inc., Lake Forest, IL) for induction of anesthesia, undergoing emergency surgery, having American Society of Anesthesiologists (ASA) physical class of 4 or greater, those in whom the use of a laryngeal mask airway was planned, oropharyngeal or facial pathologic condition that precluded mask ventilation, or anyone deemed to be at high risk of aspiration by the primary anesthesia team and in whom minimal or no mask ventilation was planned were excluded. An investigator assessed patients for eligibility the evening before planned surgery by examining the surgical case list. After patients likely to be ineligible were excluded (*i.e.*, cardiac and surgical patients are likely to receive etomidate during induction), a list of potential participants was then chosen for that day based on the availability of study

personnel during listed surgical start times. The investigator then contacted a member of the patient's primary anesthesia care team to inform them of their patient's eligibility. At the discretion of the primary anesthesia team, permission was obtained for an investigator to approach the patient for consent to participate. All anesthesia providers who provided care for study participants were experienced in providing bag-valve mask ventilation.

After written informed consent was obtained, participants were randomized by a single coin flip to single-handed followed by two-handed facemask ventilation or *vice versa*. All premedications and the doses of intravenous medications given to induce anesthesia were at the sole discretion of the primary anesthesia care team. Inhalational anesthetics and neuromuscular blocking drugs were not allowed until after completion of the study protocol. Once inside the operating room (OR), standard ASA monitors were established. Each patient was positioned with his or her head on a standard pillow. Patients with a body mass index more than 30 kg/m² were positioned on a 10% incline or wedge at the discretion of the primary anesthesia team. Patients were preoxygenated by tidal breathing 6 l/min of 100% oxygen for a period of 2–3 min. Induction of anesthesia was accomplished with intravenous propofol (Diprivan®; Astra Zeneca, Wilmington, DE) with or without the concomitant administration of intravenous fentanyl. The study protocol was started once the plane of anesthesia was judged to be adequate by the primary anesthesia provider. Depth of anesthesia monitoring was not used. A disposable oropharyngeal airway (OPA) was placed in all patients after the eyelash reflex was absent before placement of the facemask to assure adequate mouth opening. Positioning of the airway was commenced in the neutral position. Except for patients in whom cervical spine extension was limited or impossible because of underlying pathologic conditions, patients were ultimately ventilated with varying degrees of neck extension as described below. For the one-handed mask technique, a jaw-thrust was performed by placing the operator's thumbs on the OPA while simultaneously pulling the mandible forward with the use of the index and second fingers of both hands. An appropriately sized adult facemask (Clear Comfort® Air Cushion Face Mask; Teleflex Medical, Research Triangle Park, NC) was then placed over the bridge of the nose and mouth, followed by a chin-lift, head-tilt maneuver. For the two-handed technique, the facemask was first placed over the bridge of the nose and mouth and then held in place by performing a two-handed jaw thrust maneuver with the index and second fingers of each hand and maintaining mask contact with the patients face by using both thumbs. A head-tilt was performed by applying a caudad force on the mandible and mask. The anesthesia provider then indicated to the investigator that they were ready, at which time the mechanical ventilator of the anesthesia machine was started. Airway positioning was not maintained during the crossover period between techniques, which was extremely brief. For each technique, the positioning was started anew as described

above with the exception of the OPA, which was left in place for the duration of the study period.

Ventilation commenced after the patient was unresponsive to a jaw thrust. All mechanical breaths were delivered with a peak pressure of 15 cm H₂O, an inspiratory-to-expiratory ratio of 1:1, at a frequency of 15 breaths per minute, by a 7900 SmartVent contained in the S/5 Avance Carestation (Datex-Ohmeda Avance; GE Healthcare, Waukesha, WI) with a delivered-to-displayed volume (the former measured at patient wye; the latter measured by a flow sensor in the expiratory limb of the breathing circuit) accuracy of 10 ml at volumes less than 60 ml, 18 ml at volumes less than 210 ml, and less than 9% at volumes more than 210 ml. Compliance of the anesthesia circuit is measured during the automated computerized machine checkout. Flow sensors in the inspiratory limb of the breathing circuit measure the driving pressure 250 times per second and compensate for any leaks in the system by automatically increasing flow gas to maintain the set peak pressure up to 4 cm H₂O above the set positive end-expiratory pressure.§ The fresh gas flow of 6 l of oxygen was continued. The provider performing the mask ventilation was blinded to the ventilator data, which included the tidal volume measurements, by taping a piece of opaque paper over the monitor in such a way that the data collector could still visualize the monitor from behind the operator. The operator had access to the monitor displaying vital signs and a capnogram. Each technique was performed for five consecutive breaths, and the returned tidal volumes displayed on the monitor of the anesthesia machine were recorded. No repositioning of the mask was allowed after the ventilator was started. Mask leak was assessed as either audible or not and recorded as such. A nurse who was not involved with the study auscultated over the patient's epigastrium during the study period to detect instances of gastric insufflation. Study personnel exited the operating room as soon as the study data were recorded and were not present for tracheal intubation attempts. Inadequate mask ventilation (MV_i) and dead-space ventilation (V_{ds}) were defined *a priori* as an average returned tidal volume (V_t) of less than 4 ml/kg of predicted body weight (PBW) and an average returned V_t of less than 150 ml/breath associated with clinical signs (inadequate chest rise, no fogging in the mask, no positive tracing of end-tidal carbon dioxide, and/or lack of measurable returned tidal volumes on the anesthesia monitor), respectively. PBW was calculated with the use of the National Heart, Lung and Blood Institute Acute Respiratory Distress Syndrome Network formula.|| The study could be terminated at the discretion of the primary anesthesia team if ventilation was inadequate by clinical criteria, oxygen satu-

ration was less than 90%, or the primary anesthesia team believed for any reason that immediate tracheal intubation was warranted.

Baseline patient characteristics were recorded and included: age, sex, height, weight, and ASA physical status. Each participant underwent an independent airway exam by a study investigator before operation. The presence of limited cervical spine motion, the inability to protrude the lower teeth past the upper incisors, the presence of a beard, lack of dentition, or a large or extremely wasted face was recorded on a data collection sheet separately from the operative record. In addition, the sex of the operator and the maximal distance from the tip of the thumb straight across to the tip of the little finger was measured. Each operator was asked to maximally spread his or her fingers and then place the left hand on a blank white sheet of paper. Two marks were made and the distance between them was measured. The primary outcomes were total minute ventilation (V_E) in liters per minute calculated as the sum of the five breaths for each technique multiplied by three and the exhaled V_t achieved in milliliters per kilogram of PBW, averaged over the five breaths of each technique. Second, we compared the frequency of MV_i and/or V_{ds} for each technique.

Based on pilot data (20 patients) showing an increase in V_t of 3.1 (SD 2.9) ml/kg PBW when during use of a two-handed technique, we estimated that a sample size of 41 patients would be needed to detect a 30% difference in the primary outcome (V_E) with 90% power.

Statistical Analysis

To account for operator effect on multiple patients and multiple techniques in the same patient (within patient variability), a linear mixed-effects model with the operator set as a random effect, the patient nested within operator, and a simple variance components covariance structure was developed to estimate the difference in V_E and V_t between the two techniques. Covariates assessed for their interaction with the primary outcomes were patient age, body mass index, the presence of poor neck extension, jaw protrusion, or lack of teeth, significant facial hair, operator gender and hand measurement, order of technique, and induction medications. Differences of V_t between the first and fifth breath within technique and order grouping were assessed with paired *t* tests. Comparison of techniques with regard to frequency of MV_i or V_{ds} was examined by using a McNemar test for paired binary data. Data were analyzed by using R version 2.9.1 (R Foundation for Statistical Computing, Vienna, Austria). Unless otherwise noted, data are presented as mean ± SD or frequency (%). Statistical significance was defined as a two-sided *P* value less than 0.05.

Results

Forty-eight patients were assessed as eligible. In one case, permission was not granted for the patient to be approached for consent; in another case, personnel were not available to

§ GE Healthcare, Avance brochure, 2006. Available at: <http://www.gehealthcare.com/us/en/anesthesia/docs/an4583a.pdf>. Accessed March 8, 2010.

|| Acute Respiratory Distress Syndrome (ARDS) Network, National Heart, Lung, and Blood Institute, PBW tables for men and women. Available at: http://www.ardsnet.org/system/files/pbwtables_2005-02-02_0.pdf. Accessed February 1, 2010.

Table 1. Baseline Characteristics

Age, yr	56 ± 18
Male, n (%)	18 (42.9)
ASA Physical Status	2 (1–4)
Height, cm	168 ± 9.8
Weight, kg	82 ± 17
BMI, kg/m ²	30 ± 7.1
PBW, kg	61 ± 11
Risk Factors for DMV, n (%)	
None	10 (23.8)
1	13 (31)
2	10 (23.8)
3	4 (9.5)
4	3 (7.1)
5	2 (4.8)

Data are presented as mean ± SD or median (range) unless otherwise noted.

ASA = American Society of Anesthesiologists; BMI = body mass index; DMV = difficult mask ventilation; PBW = predicted body weight.

procure consent from the patient; one patient withdrew consent before entering the OR; one patient was enrolled but did not undergo the study procedure because the primary team decided upon use of a laryngeal mask for airway management once the patient was in the OR; one patient was given etomidate and not propofol; and in one case, the primary anesthesia team decided to allow a less experienced provider to mask the patient for educational purposes once in the OR. Thus, there were 42 analyzable participants. There were no missing data in any of the variables used for analysis; therefore, no imputation or analysis adjustments were required. Twenty-seven operators performed the ventilating tasks on one to five patients. Sixteen operators (59%) were male and 11 (41%) were female. Men's finger spans were larger than that of their female counterparts (21.2 ± 0.93 vs. 20.2 ± 1.3 cm; $P = 0.037$). No patient had more than one operator. Eighteen operators (66.7%) ventilated only one patient, six operators (22.2%) ventilated two patients, one operator (3.7%) ventilated three patients, and two operators each ventilated four and five patients, respectively. Baseline characteristics and the prevalence of published risk factors for difficult mask ventilation (taken to be risk factors for MV_i) are presented in tables 1 and 2. Twenty-two (52.4%) of the patients were initially ventilated with the use of the one-hand

Table 2. Prevalence of Specific Risk Factors for DMV

Age > 55 yr, n (%)	22 (52.4)
BMI > 30 kg/m ² , n (%)	17 (40.5)
Cannot Protrude Lower past Upper Teeth, n (%)	6 (14.3)
Facial Hair, n (%)	3 (7.1)
History of Snoring or OSA, n (%)	10 (23.8)
Edentulous, n (%)	9 (21.4)
Limited Cervical Spine Extension, n (%)	5 (11.9)
Large Face, n (%)	3 (7.1)

BMI = body mass index; DMV = difficult mask ventilation; OSA = obstructive sleep apnea.

technique and 20 were initially ventilated with the use of the two-hand technique. Anesthesia was induced with 1.2 ± 0.46 µg/kg fentanyl and 2.2 ± 0.63 mg/kg propofol intravenously. The V_E for the two techniques was 6.32 ± 3.24 l/min with one hand and 7.95 ± 2.70 l/min with two hands. The V_t was 6.80 ± 3.10 ml/kg PBW with one hand and 8.60 ± 2.31 ml/kg PBW with two hands. No significant interactions between technique and other covariates were found. There was a significant difference in V_E and V_t between the two techniques effect, 1.63 (95% CI, 1.16, 2.10) l/min (P less than 0.001) and effect, 1.80 (95% CI, 1.29, 2.32) ml/kg PBW (P less than 0.001), respectively (table 3). Mixed regression modeling of the relationship between V_E, breath, and technique estimated that with each additional breath (beginning from the first breath) there was an increase on average of 14 ml (95% CI, 8.4, 19.5; P less than 0.001) indicating that increasing depth of anesthesia over time may have been a factor in larger V_t. Analysis of the first-to-fifth breath changes in V_t for each technique and the order in which they were used is presented numerically in table 4 and graphically in figure 1. Use of the two-handed technique consistently and significantly resulted in larger V_t than use of the one-hand technique.

MV_i or V_{ds} occurred more frequently during use of the one-handed technique. Eight of the 42 patient trials were classified as MV_i (14%) by lack of chest rise, fog in the mask, and positive tracing of end-tidal carbon dioxide or V_{ds} (5%) during use of the one-handed technique, whereas 0 patient trials were classified as MV_i or V_{ds} during use of the two-handed technique ($P = 0.013$). No audible air leak around the mask or gastric insufflation by auscultation over the epigastrium was observed in any patient with either technique. The study was not terminated in any patient. The lowest oxygen saturation noted at any time during the study period among all patients was at least 90%.

Discussion

The main findings of our study are that ventilating apneic patients after the induction of anesthesia with PCV by using two hands to generate a triple airway maneuver provided greater upper airway patency as evidenced by greater air movement per breath than when the generic single left-handed grip was used. Further, the incidence of MV_i or V_{ds} was significantly reduced and the use of the mechanical ventilator to deliver breaths resulted in no detectable gastric insufflation. Because an OPA was placed and two-handed mask ventilation performed in every patient as part of the study protocol, we could not classify mask ventilation as either difficult or impossible by recently published criteria,^{8–10} nor could we employ a previously published grading scale.¹¹ Although the ASA Task Force includes “absent or inadequate ... spirometric measures of exhaled gas flow” in their definition of difficult mask ventilation,^{12,13} this is not routinely used by practitioners in isolation without other subjective clinical criteria of difficulty or development of

Table 3. Comparison by Technique

	One-Hand	Two-Hand	Effect (95% CI)	P Value
V_E , l/min average (SD)	6.32 (3.24)	7.95 (2.70)	1.63 (1.16, 2.10)	< 0.001
V_t , ml/kg PBW average (SD)	6.80 (3.10)	8.60 (2.31)	1.80 (1.29, 2.32)	< 0.001
MV_i or V_{ds} , n (%)	8 (19.0)	0	—	0.013

CI = confidence interval; MV_i = inadequate mask ventilation (< 4 ml/kg predicted body weight); PBW = predicted body weight; V_{ds} = dead-space ventilation (< 150 ml, no clinical sign of ventilation); V_E = minute ventilation; V_t = tidal volume.

hypoxemia to communicate episodes of difficult mask ventilation. This may explain the discrepancy between the higher incidence of MV_i and V_{ds} we report and those previously reported for difficult and impossible mask ventilation.

Ventilation is defined objectively as the volume of gas entering and exiting the lungs each minute (V_E). More precisely, gas exchange at the level of the alveolus, alveolar ventilation, determines the arterial tension of carbon dioxide. In turn, alveolar ventilation is determined by the interaction of breathing frequency, V_E , and the ratio of dead space to V_t (V_d/V_t). Thus, in physiologic terms, adequacy of ventilation can be objectively assessed only in clinical settings by examining exhaled gas flows or arterial carbon dioxide tension. Absolute values of exhaled carbon dioxide as exhibited on the anesthesia monitor as a surrogate for alveolar ventilation without specific knowledge of the actual arterial carbon dioxide is of dubious value because V_d/V_t must then be inferred. Based on this fundamental understanding, we chose *a priori* to define MV_i as the inability to provide a minimal weight-adjusted volume of air per breath and V_{ds} simply as the inability to provide enough air per breath to ventilate more than the average adult anatomical dead space (150 ml). Arterial oxygenation as reflected by the pulse oximeter, on the other hand, reflects the balance of global oxygen delivery and uptake as well as the ability of the airway manager to maintain a near normal shunt fraction by using positive pressure to maintain the functional residual capacity. None of our patients had a pulse oximetry reading of less than 90%, which might lead some to conclude that the improvements in ventilation seen in our study have less clinical relevance than if these same changes occurred in the setting of hypoxemia. However, the lack of hypoxemia must be placed within the context of our study design. Our patients were all undergoing elective surgery, were well preoxygenated, and would be presumed to have an oxygen delivery well in excess of demand even before induction of anesthesia. Therefore, even in the event of an impossible mask ventilation scenario, we

would not have expected hypoxemia to result during a total study period of approximately 1 min.

Insofar as all breaths were delivered with the use of PCV *via* the anesthesia machine, our study design assumes a constant peak inspiratory pressure without which we would be unable to distinguish between mask leak and upper airway obstruction as the reason for reduced V_t . Because we only listened for air leaks around the mask, our rudimentary technique could have underestimated the size of the leak. Nonetheless, because no audible air leak was noted during the study and our ventilator compensates for air leaks while in PCV mode, we believe pressure dissipation could have only occurred in the upper or lower airways. Because both techniques were performed in crossover fashion on each patient, changes in lower respiratory system compliance do not explain our findings, and we conclude that improved upper airway patency resulting in lower resistance to airflow when during the use of a two-handed mask hold accounted for the improved air entry. The accuracy of our V_t measurements are crucial, particularly to correctly categorize MV_i and V_{ds} in our study. Measurements obtained during PCV with the use of a mechanical lung model and a calibrated pneumotachograph have reported that the anesthesia machine monitor of the Avance SmartVent 7900 overestimates the delivered volumes by 7–40% depending on whether the circuit is fully collapsed or fully extended. This is true only when the delivered volumes are small (< 150 ml). At higher volumes, up to 500 ml, the accuracy is $\pm 5\%$ ¹⁴ and agrees with manufacturer's published technical specifications. Had we used a calibrated pneumotachograph to directly measure the delivered volumes, our reported values would likely have been slightly lower, but the differences found between the two techniques and our conclusions based upon them would remain the same.

Other specific controversies and limitations deserve clarification. Our protocol did not allow for administration of neuromuscular blocking drugs. It has been hypothesized that residual muscle tone after the induction of anesthesia results

Table 4. Comparisons of Tidal Volumes by Technique and Sequence from First to Last Breath

Technique and Sequence	Breath 1	Breath 2	Breath 3	Breath 4	Breath 5	P Value*
One Hand First, ml	412 (254)	444 (243)	453 (250)	467 (228)	455 (241)	0.084
One Hand Second, ml	380 (190)	383 (206)	399 (220)	404 (198)	405 (205)	0.419
Two Hands First, ml	454 (176)	501 (193)	516 (178)	536 (159)	566 (165)	0.006
Two Hands Second, ml	514 (201)	535 (203)	547 (203)	561 (202)	563 (209)	0.030

Data are presented as mean (SD) and rounded to the nearest milliliter.

* Paired *t* test comparing breath 1 with breath 5. Statistical significance is defined as $P < 0.05$.

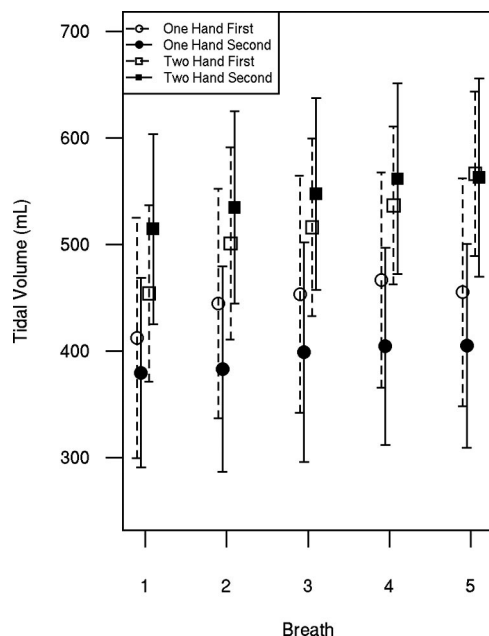


Fig. 1. Mean tidal volume (circle or square) with 95% confidence interval bands by technique and order from first to fifth breath. Use of a two-handed technique resulted in a significant increase in tidal volumes compared with use of a one-handed technique whether it was used first ($P = 0.006$) or second ($P = 0.03$).

in some resistance to mask ventilation that is interpreted by the operator as impossible mask ventilation.¹⁵ The notion that administration of a neuromuscular blocking drug with induction may have resulted in improved one-hand technique cannot be completely discounted. Our protocol reflects the standard anesthetic practice in our department at the time of the study and may not be generalizable to those situations in which neuromuscular blocking drugs are given as part of induction. In addition, each technique was not studied for a full minute; thus, the V_E is calculated from the values obtained over the 20-s study period. It is possible that operator-related factors such as fatigue could have resulted in poorer performance with a two-handed technique over time and that the results for both techniques would have been similar. Arguing against this is the finding that mask ventilation with the two-handed technique resulted in higher V_t both initially and over the course of the five study breaths compared with use of the standard one-handed technique. In addition, differences in the magnitude of improvement seen between the two- and one-handed techniques may have been underestimated. The use of an OPA as part of the study protocol may have improved upper airway patency by bypassing the velopharynx, the narrowest portion of the upper airway, and aiding in performing the triple airway maneuver, chiefly mouth opening. Last, although determination of operator and patient-related risk factors for reductions in V_E and V_t are of great interest, our study was not adequately powered for such an analysis.

Our findings support the notion that the anesthesiologist is unable to advance and maintain the mandible forward an

adequate distance when using only one hand to hold the jaw. This is particularly important because changes to the retro-palatal cross-sectional area differ in response to a jaw thrust between obese and nonobese patients, whereas the retro-glossal airway does not.¹⁶ Therefore, in our experimental model, which bypassed the retro-palatal airway with the use of an OPA, the ability to decrease upper airways resistance would have been totally dependent on changes in the retro-glossal airway, moving the epiglottis away from the posterior pharyngeal wall, and the diameter of the vocal cord inlet. Relief of obstruction at these sites has been demonstrated with use of mandibular advancement with or without the application of continuous positive end-expiratory pressure.^{17–20} Because positive end-expiratory pressure was not used in our study, maintenance of upper airway patency was totally dependent on simple mechanical interventions. Finally, an increase in lung volumes, enabled by greater upper airway patency with mandibular advancement in the two-handed group, might have resulted in maintenance of the anatomical balance in the pharyngeal airway by increasing longitudinal traction forces.²¹ In other words, greater tidal volumes beget greater tidal volumes. We believe that our findings provide physiologic data complementary to those in the sentinel work of Safar *et al.*^{1,2} over 50 yr ago and support the opinion of a recent editorial suggesting that a two-handed jaw thrust mask hold technique with breaths delivered by the mechanical ventilator of the anesthesia machine rather than the “EC-clamp” mask-hold technique is optimal for mask ventilation.²²

Data collected in the operating room setting indicate that difficult mask ventilation is infrequent (less than 1.5 per 100 mask ventilations¹⁰) and impossible mask ventilation is rare (1.5 per 1000 mask ventilations²³). This suggests that the commonly employed single left-handed “EC-clamp” mask hold technique with continuous positive airway pressure is successful in the overwhelming majority of elective, well prepped surgical patients. Our findings suggest that those displaying high-risk features for ventilation difficulty or those with limited physiologic reserve may benefit from two-hand mask ventilation as we describe from the outset. However, a strong statement regarding the clinical advantages of two-hand mask ventilation over the single-handed technique in a larger more varied group of patients based on observations during only 10 breaths in our study should be avoided. Nonetheless, our findings add to the current understanding of common anesthesia practice and thus affect anesthesia education. In addition to a longer study period, future investigations should focus on specific patient populations who may derive greater benefit from the use of a two-handed triple airway maneuver as we describe preferentially at the outset of ventilation with and without an OPA as well as the effects of administered neuromuscular blocking drugs.

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