Resuscitation 81 (2010) 1161–1165

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Simulation and education

An evaluation of bag-valve-mask ventilation using an ergonomically designed facemask among novice users: A simulation-based pilot study☆

Eric B. Bauman[a,*], Aaron M. Joffe[b], Lynn Lenz[c], Stephen A. DeVries[d], Scott Hetzel[e], Samuel P. Seider[f]

[a] Department of Anesthesiology, University of Wisconsin School of Medicine and Public Health, Madison, WI, United States
[b] Department of Anesthesiology and Pain Medicine, University of Washington-Harborview Medical Center, Seattle, WA, United States
[c] Director of Clinical Education, Respiratory Care, Western Technical College, La Crosse, WI, United States
[d] Tri-State Ambulance, La Crosse, WI, United States
[e] Department of Biostatistics and Medical Informatics, University of Wisconsin-Madison, Madison, WI, United States
[f] College of Letters and Science, University of Wisconsin-Madison, Madison, WI, United States

ARTICLE INFO

Article history:
Received 31 January 2010
Received in revised form 4 May 2010
Accepted 7 May 2010

Keywords:
Resuscitation
Airway management
Facemask
Ventilation

ABSTRACT

Purpose: We sought to compare the ability of novice operators to provide artificial ventilation using a standard facemask and a new ergonomically designed facemask. Whether or not proper technique was used was also assessed.
Methods: Thirty-two allied-health students used both masks in random crossover fashion to ventilate an airway trainer. Breaths were delivered by a mechanical ventilator and exhaled tidal volume was recorded for each of 12 breaths for each participant for each mask. The effect of each mask during ventilation over time was assessed using repeated-measures ANOVA. Assessment of mask technique among participants and association between mask type and hand repositioning were analyzed using the Wilcoxon-Rank Sum Test and McNemar's paired proportions test, respectively.
Results: The tidal volume achieved when participants used the ergonomic mask was higher than when participants used the standard mask by the fourth breath (361 ± 104 mL vs. 264 ± 163 mL; Bonferroni adjusted p-value = 0.040) and increased over time. The repeated-measures ANOVA showed that the ergonomic mask consistently resulted in higher tidal volumes than the standard mask regardless of rescuer's gender. Over time the standard mask resulted in a linear decrease in tidal volume of −10 mL/breath (estimated difference in decay of 10 mL/breath versus the ergonomic mask; $p < 0.001$).
Conclusion: Novice airway operators were better able to provide facemask ventilation using an ergonomically designed mask than with a traditional facemask. We conclude that better hand position facilitating improved mask seal and less operator fatigue account for our findings.

1. Introduction

Providing adequate oxygenation and ventilation for an apnoeic patient is the primary goal of rescuer-provided artificial ventilation. Traditionally, this has been performed using a self-inflating resuscitation circuit interfaced with a facemask, generically referred to as bag-valve-mask (BVM). Generation of an effective seal between the mask and the patient's face in order to establish and maintain upper airway patency is needed for effective BVM ventilation.

Efficacy of BVM ventilation is dependent on the interaction between operator-dependent variables such as experience,[1–3] hand size,[4] gender,[5] and patient-dependent variables including obesity, facial hair, lack of teeth, age, limited cervical spine motion, and facial anatomic features impeding a mask seal.[6–8] In addition, situation-dependent variables including mask ergonomics, environmental familiarity, and the presence or absence of distractions will also influence the effectiveness of artificial ventilation with a BVM.[9] Given the number of variables at play in stressful and unfamiliar environments surrounded by distractions, it is not surprising that rescuers with limited airway management experience are unable to provide adequate BVM ventilation.[10]

The ErgoMask™ (EM, King Systems, Noblesville, IN) is a new facemask designed to ergonomically fit the clinician's hand. It is available as a left-handed device only (Fig. 1). This design may enable better contact between the operator's hand and the mask, avoid hand fatigue, and allow for better control of the facemask resulting in a better mask seal. In addition, an ergonomic hand position may be more effective in maintaining patient positioning maneuvers such as the head-tilt/chin-lift that facilitate upper airway patency.[11] We hypothesized that an ergonomic face-

☆ A Spanish translated version of the summary of this article appears as Appendix in the final online version at doi:10.1016/j.resuscitation.2010.05.005.

* Corresponding author. Tel.: +1 608 263 5911.
E-mail address: ebauman@wisc.edu (E.B. Bauman).

0300-9572/$ – see front matter © 2010 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.resuscitation.2010.05.005

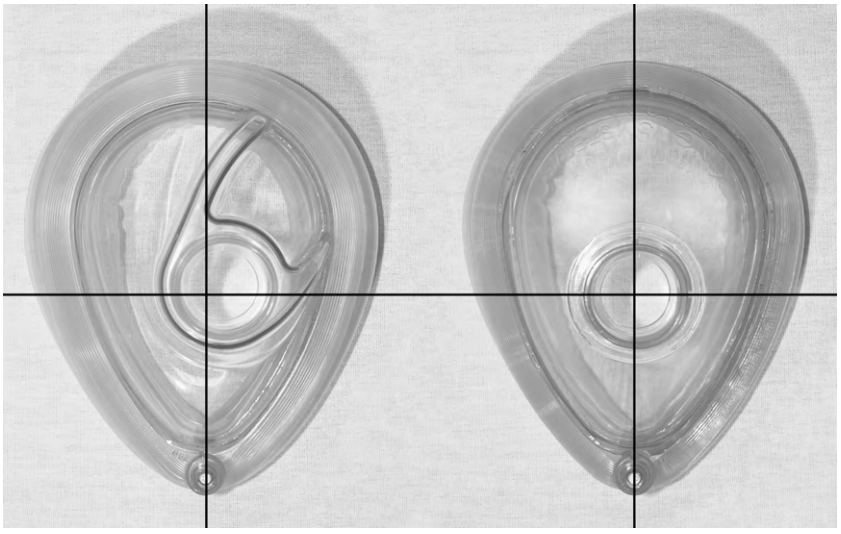

Fig. 1. Side-by-side comparison of the ErgoMask™ (left) and standard mask (right).

mask would promote better technique among novice operators with limited or little experience providing BVM ventilation. We also hypothesized that using an ergonomically designed facemask would promote more effective ventilation. The purpose of this study was two-fold. First, we sought to compare the ability of novice operators to provide artificial ventilation using both a standard facemask (SM) and the EM and second, to compare the operator's ability to use adequate technique for each mask.

2. Methods

Participants were 32 allied-health students with minimal airway management training. The convenience sample included 6 emergency medical technician students (EMT), 9 paramedic students, and 17 respiratory therapy students enrolled at a Midwest technical college. Twelve (37.5%) of the subjects were men and 20 (63.5%) were women. The mean age for all participants was 28 years old. All participants had taken the American Heart Association Basic Life Support course at least once as a prerequisite to their current training program. This curriculum provides specific training on rescue breathing with a BVM. Additional basic training in rescue breathing and BVM ventilation technique is included as part of the EMT, paramedic and respiratory therapy curricula at the technical college. Instructional staff from the college's Respiratory Therapy and Paramedic programs collected all data. Primary investigators were not involved in data collection. The ethics committee of Western Technical College (La Crosse, Wisconsin) and the Health Sciences Institutional Review Board at the University of Wisconsin-Madison approved the study.

Prior to data collection, a brief tutorial was provided to each participant about the proper use of the SM and the EM. For the SM, participants were instructed to use the "E-C" technique as prescribed by the American Heart Association guidelines for emergency cardiac care in which the thumb and forefinger form a "C" shape over the mask and exert downward pressure on the mask while the third, fourth, and fifth fingers (forming an E) are positioned along the jaw to maintain the jaw thrust.[12] For the EM, participants were instructed in its use per manufacturer recommendations (Fig. 2). The SM used for all procedures was a single-use medium size adult mask (Clear Comfort® Air-Cushion FaceMask, Teleflex Medical, Research Triangle Park, NC) with the o-ring removed. One SM and EM were reused for all study procedures. Each participant performed all study procedures using both SM and EM in a random, crossover fashion.

A single left-handed technique was used with both masks. Participants were asked to perform basic airway maneuvers, including opening the airway and properly placing the facemask on a Laerdal®Airway Management Trainer (Laerdal Medical Corporation, Wappingers Falls, NY). After obtaining a mask seal, breaths were delivered using a Pulmonetics LTV®1200 volume-cycled ventilator (CareFusion, San Diego, CA) set to deliver a tidal volume of 500 mL, 12 times per minute, at an inspiratory-to-expiratory ratio of 1:4 (cycle-length 5 s). In order to simulate actual BVM ventilation, participants squeezed a breathing bag with their free hand in time with each ventilator-delivered breath. The experimental setup is shown in (Fig. 3). The exhaled tidal volume was recorded for each of 12 breaths by the ventilator for each participant using both the SM and the EM. During performance of each study procedure, two non-blinded expert observers evaluated participants on airway positioning, hand technique, quality of mask seal, and maintenance of mask seal over time using a one through six Likert-style scale with one representing the poorest possible technique and six the best possible technique. Repositioning of the airway and/or the mask during the data collection period was also recorded. The study protocol only sought to evaluate the effectiveness of ventilation by simulating artificial or rescue breathing using a BVM and two different types of facemasks. This study did not attempt to address effectiveness of ventilation during cardio-pulmonary resuscitation (CPR) or any component related to circulation.

Fig. 2. Top view of th ErgoMask™ in use on the Laerdal® Airway Management Trainer. The recommended asymmetric left-handed grip is demonstrated.