American Red Cross
American Red Cross Advisory Council on First Aid, Aquatics, Safety and Preparedness

# ACFASP Scientific Review

## Bag-valve-mask versus mouth to mask

## Ventilation for single rescuer

**Questions to be addressed:**

In the non-breathing person cared for by a single-rescuer, which technique leads to better ventilation: bag-valve-mask or mouth-to-mask? In the non-breathing person cared for by a multiple-rescuers, which technique leads to better ventilation: bag-valve-mask or mouth-to-mask?

**Introduction/Overview:**

The first reports of mouth-to-mouth resuscitation in medical literature date from the 1700s (Elam, 1954). Despite the apparent success of this simple procedure, it did not find favor until experiments in the late 1950s proved its superiority over other available methods (Safar, 1958). Until then, manual techniques predominated. One reason for this was the reluctance of rescuers to come into such close, intimate contact with the victim. This may be the most significant drawback to the mouth-to-mouth approach (Brenner, et al, 1994). In response to this problem, ways of delivering expired air ventilation while avoiding direct contact with the victim have been developed. One of the first involved the use of an anesthesia mask to provide mouth-to-mask breathing (Elam, 1954).

Mechanical devices have been used to ventilate victims since at least the 18th century. At first, these were simple fireplace bellows (Eisenberg**,** 1997). By the late 1920's, oxygen-powered, automatically cycling portable resuscitators were developed (L. N. Curtis and Sons website). These machines had the drawbacks of being large, heavy, and complex, and were dependant on an oxygen supply to operate. However, for many years, they were the only available option. Finally, in 1956, a new device entered the market. The Ambu A/S Company introduced a simple, self-inflating bag-valve-mask (BVM) device (Ambu A/S website). It was lightweight, compact, could be used almost anywhere, and did not require an oxygen supply to operate. This device quickly gained widespread acceptance.

Despite the success of the BVM, the utility of the method has been called into question. In a series of experiments conducted in the 1980s, several teams of researchers found that many rescuers had significant difficulties using the BVM to successfully ventilate manikins (Harrison, et al, 1982; Elling, et al, 1983). The main problem, they noted, was that the users of a BVM needed to accomplish three distinct tasks simultaneously. First, the rescuer needed to seal the mask to the victim's face. Secondly, the airway had to be opened and maintained. Finally, the rescuer had to squeeze the bag sufficiently to deliver the necessary volume. Since then, others have compared BVM ventilation by one rescuer with its

use by two rescuers, one to seal the mask and open the airway, and the second to squeeze the bag. These studies suggested that the two-rescuer/four-hand technique was superior (Wheatley, et al, 1997).

Mouth-to-mask ventilation experienced an increase in popularity in the mid-1970s, when a modified device became available. The Laerdal Corporation added a head strap and oxygen inlet to its folding Pocket Mask ™ model of resuscitation mask.. This produced a device that could be easily carried by a rescuer, and strapped to a victim during one-rescuer CPR. It enabled the rescuer to ventilate with expired air while avoiding direct contact, and deliver oxygen to both breathing and non-breathing victims. Proponents observed that this device was actually easier to use than a BVM, and first began to suggest that the mouth-to-mask technique could replace BVM ventilation, especially for rescuers with minimal training or limited opportunities to practice (Safar, 1974).

**Review Process and Literature Search Performed**

PubMed and Medline searches were performed using the MeSH terms *CPR* AND *Heart Arrest* AND *Respiration, artificial*. Next, these databases were searched using the keywords *bag-valve-mask, pocket mask,* and *mouth-to-mask ventilation*. 644 abstracts were retrieved, screened for duplications, and reviewed. 23 papers were obtained and reviewed.

Four additional papers were located and obtained from other sources, along with a book containing pertinent information. Finally, the websites of two manufacturers were identified and provided relevant historical data.

**Summary of Key Articles/Literature Found and Level of Evidence:**

| Author(s) | Full Citation | Summary of Article | Level of Evidence |
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| (Elam, Brown and Elder, 1954) | Elam, J. O., Brown, E. S. and Elder, J. D., Jr. (1954). Artificial respiration by mouth-to-mask method; a study of the respiratory gas exchange of paralyzed patients ventilated by operator's expired air. *N Engl J Med,* **250**(18), | Demonstrated acceptable blood gases with mouth-to-mask as compared to mouth-to-tracheal tube ventilation on post-operative patients with apnea induced with | 2c |

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| | 749-54. | succinylcholine. | |
| (Safar, 1958) | Safar, P. (1958). Ventilatory efficacy of mouth-to-mouth artificial respiration; airway obstruction during manual and mouth-to-mouth artificial respiration. *J Am Med Assoc,* **167**(3), 335-41. | Tested 167 untrained rescuers administering artificial respirations to 25 victims paralyzed with succinylcholine. Demonstrated the efficacy of the mouth-to-mouth and mouth-to-S tube methods and the ineffectiveness of the back-pressure/arm lift and chest pressure/arm lift techniques. | 2a |
| (Safar and McMahon, 1958) | Safar, P. and McMahon, M. (1958). Mouth-to-airway emergency artificial respiration. *J Am Med Assoc,* **166**(12), 1459-60. | This paper does not describe the experimental technique other than stating success in using the S tube in 87 volunteers as measured by oximetry. | 2c |
| (Safar, 1974) | Safar, P. (1974). Pocket mask for emergency artificial ventilation and oxygen inhalation. *Crit Care Med,* **2**(5), 273-6. | Describes an adaptation of a Laerdal Pocket Mask ™ for artificial ventilation, and gives the<br><br>result of an experiment on one subject. | 3b |
| (Harrison, Maull *et al.*, 1982) | Harrison, R. R., Maull, K. I*., et al.* (1982). Mouth-to-mask ventilation: A superior method of rescue breathing. *Ann Emerg Med,* **11**(2), 74-6. | Studied 22 volunteers ventilating adult-sized manikins with one of five methods. Demonstrated good ventilation with mouth-to-mask, as compared to one-rescuer BVM, with significant intra-rescuer variability. | 4 |
| (Elling and Politis, 1983) | Elling, R. and Politis, J. (1983). An evaluation of emergency medical technicians' ability to use manual ventilation devices. *Ann Emerg Med,* **12**(12), 765-8. | Demonstrated superior ventilations using mouth-to-mask as compared to one-rescuer BVM with 320 EMTs ventilating adult-sized manikins. | 4 |
| (Hess and Baran, | Hess, D. and Baran, C. (1985). Ventilatory volumes using mouth-to-mouth, mouth-to- | This adult-sized manikin study compared the performance of 24 | 4 |

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| 1985) | mask, and bag-valve-mask techniques. *Am J Emerg Med,* **3**(4), 292-6. | respiratory therapists. Mouth-to-mask and two-rescuer BVM were equivalent, but there were significant decreases in volumes of air delivered with one-rescuer BVM. | |
| (Lawrence and Sivaneswaran, 1985) | Lawrence, P. J. and Sivaneswaran, N. (1985). Ventilation during cardiopulmonary resuscitation: Which method? *Med J Aust,* **143**(10), 443-6. | 35 doctors and nurses had no difficulty ventilating adult-sized manikins when using either the mouth-to-mouth or mouth-to-mask method. Only a single subject could successfully perform one-rescuer BVM ventilation. | 4 |
| (Stewart, Kaplan *et al.*, 1985) | Stewart, R. D., Kaplan, R.*, et al.* (1985). Influence of mask design on bag-mask ventilation. *Ann Emerg Med,* **14**(5), 403-6. | This study compared three different masks for BVM ventilation. | 4 |
| (Palme, Nystrom and Tunell, 1985) | Palme, C., Nystrom, B. and Tunell, R. (1985). An evaluation of the efficiency of face masks in the resuscitation of newborn infants. *Lancet,* **1**(8422), 207-10. | This study compared various types of masks used with a BVM while ventilating 44 healthy infants. Air leak was inferred by pressure differential between the ventilator and the mask. | 3b |
| (Cummins, Austin *et al.*, 1986) | Cummins, R. O., Austin, D.*, et al.* (1986). Ventilation skills of emergency medical technicians: A teaching challenge for emergency medicine. *Ann Emerg Med,* **15**(10), 1187-92. | This study of 64 EMTs found no significant difference in delivering successful ventilations (as defined by making the green light flash 12 times per minute) on an adult-sized recording manikin when one-rescuer BVM was compared to mouth-to-mask use. | 4 |
| (Terndrup, Kanter and Cherry, 1989) | Terndrup, T. E., Kanter, R. K. and Cherry, R. A. (1989). A comparison of infant ventilation methods performed by prehospital personnel. *Ann Emerg Med,* **18**(6), 607-11. | 59 EMT-Ps had significantly better rates of 'acceptable breaths' (adequate volume delivered) in ventilating infant-sized manikins when using mouth-to-mouth, one-rescuer BVM, and mouth-to-mask using an infant-sized mask as compared to using a adult-sized | 4 |

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| | | Laerdal Pocket Mask ™. | |
| (Johannigman, Branson *et al.*, 1991) | Johannigman, J. A., Branson, R. D.*, et al.* (1991). Techniques of emergency ventilation: A model to evaluate tidal volume, airway pressure, and gastric insufflation. *J Trauma,* **31**(1), 93-8. | Fifteen paramedics ventilated an adult-sized manikin with a test lung at various compliance levels using mouth-to-mouth, mouth-to-mask and one-rescuer BVM. Outcome measures were tidal volume and gastric insufflation. With decreased compliance, rescuers were unable to deliver adequate tidal volumes with the one-rescuer BVM method. | |
| (Greenslade, 1991) | Greenslade, G. L. (1991). Single operator cardiopulmonary resuscitation in ambulances. Which ventilation device? *Anaesthesia,* **46**(5), 391-4. | Seventeen paramedics ventilated an adult-sized manikin during CPR using mouth-to-mouth, mouth-to-mask, and one-rescuer BVM techniques. Using minute ventilation as the outcome measure, mouth-to-mouth and mouth-to-mask were superior to one-rescuer BVM, especially in a moving ambulance. | 4 |
| (Cydulka, Connor *et al.*, 1991) | Cydulka, R. K., Connor, P. J.*, et al.* (1991). Prevention of oral bacterial flora transmission by using mouth-to-mask ventilation during CPR. *J Emerg Med,* **9**(5), 317-21. | This study compared different mask devices to assess their ability to prevent transmission of oral microbes from the victim to the rescuer. | 4 |
| (Terndrup and Warner, 1992) | Terndrup, T. E. and Warner, D. A. (1992). Infant ventilation and oxygenation by basic life support providers: Comparison of methods. *Prehosp Disaster Med,* **7**(1), 35-40. | There was no significant difference in delivered volumes between the mouth-to-mouth, mouth-to-mask, and one-rescuer BVM methods when 50 EMTs ventilated infant-sized manikins. | 4 |
| (Thomas *et al.*, 1992) | Thomas, A. N.*, et al.* (1992). A new technique for two-hand bag valve mask ventilation. *Brit. J Anaesthesia,* **69**, 397-398. | This study compared tidal volumes achieved from 18 subjects ventilating an adult-sized manikin using different techniques of squeezing a bag-valve-mask, | 4 |

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| | | including two-rescuer BVM. | |
| (Thomas *et al.*, 1993) | Thomas, A. N.*, et al.* (1993). A comparison of bag mask and mouth mask ventilation in anaesthetised patients. *Resuscitation,* **26**, 13-21. | This study compared ventilation in 30 sedated and paralyzed humans in the operating room. Anesthesiology residents used either a one-rescuer BVM or mouth-to-mask technique. Both methods provided adequate ventilation. The mouth-to-mask technique resulted in increased airway pressure and greater gastric insufflation. | 2b |
| (Brenner, Stark and Kauffman, 1994) | Brenner, B., Stark, B. and Kauffman, J. (1994). The reluctance of house staff to perform mouth-to-mouth resuscitation in the inpatient setting: What are the considerations? *Resuscitation,* **28**(3), 185-93. | This survey of 74 Internal Medicine house staff revealed a reluctance to perform mouth-to-mouth ventilations on hospitalized patients. | 3b |
| (Brenner and Kauffmann, 1996) | Brenner, B. E. and Kauffmann, J. (1996). Response to cardiac arrests in a hospital setting: Delays in ventilation. *Resuscitation,* **31**(1), 17-23. | This report of 38 adult cardiac or respiratory arrests in one hospital demonstrated a shorter interval from recognition to ventilation when mouth-to-mask was used as compared to BVM ventilation. | 2c |
| (Hackman, Kellermann *et al.*, 1995) | Hackman, B. B., Kellermann, A. L.*, et al.* (1995). Three-rescuer CPR: The method of choice for firefighter CPR? *Ann Emerg Med,* **26**(1), 25-30. | This study of 135 fire engine companies demonstrated a higher ventilation rate, tidal volume and minute ventilation when two-rescuer BVM was compared with one-rescuer BVM, during simulated CPR on adult-sized manikins. | 4 |
| (Massawe, Kilewo *et al.*, 1996) | Massawe, A., Kilewo, C.*, et al.* (1996). Assessment of mouth-to-mask ventilation in resuscitation of asphyxic newborn babies. A pilot study. *Trop Med Int Health,* **1**(6), 865-73 | This small study, published without measures of significance, compared one-rescuer BVM to mouth-to-mask techniques when used on newborn infants by neonatal doctors and nurses. | 2c |

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| (Wheatley, Thomas *et al.*, 1997) | Wheatley, S., Thomas, A. N.*, et al.* (1997). A comparison of three methods of bag valve mask ventilation. *Resuscitation,* **33**(3), 207-10. | This study compared three different methods of using BVM by fifteen nurses in anesthetized humans. It found higher airway pressures and increased tidal volumes with the two-rescuer BVM technique. | 2b |
| (Davidovic, Lacovey and Pitetti, 2005) | Davidovic, L., Lacovey, D. and Pitetti, R. D. (2005). Comparison of 1- versus 2-person bag-valve-mask techniques for manikin ventilation of infants and children. *Ann Emerg Med,* **46**(1), 37-42. | This study of 70 subjects demonstrated greater tidal volumes and peak pressures with two-rescuer BVM than with the one-rescuer technique while ventilating infant-sized and child-sized manikins. | 4 |
| (Yildiz, Solak and Toker, 2005) | Yildiz, T. S., Solak, M. and Toker, K. (2005). The incidence and risk factors of difficult mask ventilation. *J Anesth,* **19**(1), 7-11. | This prospective study of 576 adult patients undergoing surgery found that Mallampati class 4, male gender, smoking history, increasing age, and increasing weight were risk factors for difficult mask ventilation. Overall, 7.8% of the patients were difficult to ventilate with the one-rescuer technique. | 3b |
| (Kitagawa, Nakamura and Yamamoto, 2006) | Kitagawa, K. H., Nakamura, N. M. and Yamamoto, L. (2006). Retention of pediatric bag-mask ventilation efficacy skill by inexperienced medical student resuscitators using standard bag-mask ventilation masks, pocket masks, and blob masks. *Am J Emerg Med,* **24**(2), 223-6. | This study of 46 medical students compared preferences and skill retention when comparing three different adult-sized masks for BVM ventilation of infant-sized and child-sized manikins. | 4 |
| (Paal, Falk *et al.*, 2006) | Paal, P., Falk, M.*, et al.* (2006). Comparison of mouth-to-mouth, mouth-to-mask and mouth-to-face-shield ventilation by lay persons. *Resuscitation,* **70**(1), 117-23. | This study compared the mouth-to-mouth, mouth-to-mask, and mouth-to-faceshield techniques of adult-<br><br>sized manikin ventilation for seventy high school students after a 10 minute training session. This | 4 |

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| | | study demonstrated some benefit to the mouth-to-mask technique in rescuers who had not received any prior training in first aid. | |

| Level of Evidence | Definitions **(See manuscript for full details)** |
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| **Level 1a** | Population based studies, randomized prospective studies or meta-analyses of multiple studies with substantial effects |
| **Level 1b** | Large non-population based epidemiological studies or randomized prospective studies with smaller or less significant effects |
| **Level 2a** | Prospective, controlled, non-randomized, cohort or case-control studies |
| **Level 2b** | Historic, non-randomized, cohort or case-control studies |
| **Level 2c** | Case series: convenience sample epidemiological studies |
| **Level 3a** | Large observational studies |
| **Level 3b** | Smaller observational studies |
| **Level 4** | Animal studies or mechanical model studies |
| **Level 5** | Peer-reviewed, state of the art articles, review articles, organizational statements or guidelines, editorials, or consensus statements |
| **Level 6** | Non-peer reviewed published opinions, such as textbook statements, official organizational publications, guidelines and policy statements which are not peer reviewed and consensus statements |
| **Level 7** | Rational conjecture (common sense); common practices accepted before evidence-based guidelines |
| **Level 1-6E** | Extrapolations from existing data collected for other purposes, theoretical analyses which is on-point with question being asked. Modifier E applied because extrapolated but ranked based on type of study. |

**Scientific Foundation:**

The first study of the mouth-to-mask method (Elam et al, 1954) found that the technique allowed effective ventilations to be delivered to nine adult post-operative patients. The operators could easily maintain acceptable blood levels of oxygen and carbon dioxide in their patients without experiencing

fatigue, shortness of breath, or dizziness. The authors suggested that the technique had several advantages and could be useful in emergency situations (LOE 2c).

In a study of the S tube mouth-to-airway adjunct, Safar and McMahon (1958) instructed laypersons and physicians in the use of the device. While this study did not specifically examine mouth-to-mask ventilation, it did show that rescuers with minimal training, using a simple adjunct that could be carried in a pocket, could deliver effective ventilations to an adult who was not breathing (LOE 2c).

In 1974, Safar evaluated the modified Laerdal Pocket Mask ™ previously described in the Introduction/Overview on page 3. Using one adult volunteer, he studied the use of the device with and without supplemental oxygen. While limited in size and scope, the study did show that it was possible to use the new device to deliver supplemental oxygen during ventilation of an adult (LOE 3b).

Harrison et al (1982) conducted a direct comparison of mouth-to-mask and BVM ventilation using an adult-sized manikin connected to a spirometer. With the mouth-to-mask method, subjects delivered ventilations with tidal volumes exceeding 1000 milliliters (ml). With the one-rescuer BVM technique, the tidal volumes were between 495 and 509 ml. As the authors noted, these volumes were significantly lower than the 800 ml. minimum recommended at the time (LOE 4).

In a similar study in 1983, Elling and Politis used an adult-sized recording manikin to test the ability of emergency medical technicians (EMTs) to use the two methods. The results showed that all of the subjects were able to deliver a tidal volume of greater than 800 ml when using the mouth-to-mask technique. Over 50% of the subjects failed to achieve this tidal volume when using their choice of BVM (LOE 4).

Hess and Baran (1985) conducted another adult-sized manikin study of mouth-to-mask and one-rescuer BVM that not only compared the two methods, but also examined the two-rescuer BVM technique as well. The subjects were students in a respiratory therapy program and therapists in practice. The study showed that two-rescuer BVM and mouth-to-mask ventilation delivered comparable ventilatory volumes, although less than in previous studies. One-rescuer BVM averaged about half the volume of the other techniques. Interestingly, subject's level of experience made no significant difference in their ability to deliver adequate ventilations (LOE 4).

Lawerence and Sivaneswaran (1985) studied a range of health care personnel to measure their ability to ventilate adult-sized manikins with both the mouth-to-mask and one-rescuer BVM techniques. Before conducting skill testing, they surveyed the subjects and found significant reluctance to use mouth-to-mouth ventilation, which varied depending on the circumstances. When given the option of performing mouth-to-mask ventilation using a resuscitation mask with a bacterial filter, 100% of the subjects indicated willingness to use that method. The researchers found that, as in previous studies, mouth-to-mask ventilation produced adequate tidal volumes. Using the one-rescuer BVM technique, only a single subject was able to deliver the target volume of 800 ml. The results of this study prompted the institution to discontinue use of the BVM in patients until an advanced airway was placed (LOE 4).

Two studies in 1985 looked at the impact of mask shape on one-rescuer BVM ventilation. Stewart et al compared a new mask consisting of a round, partially inflated cushion mounted to a flat, flexible disc (Seal Easy ®, by Respironics) with two common brands of more traditional design. When used to ventilate adult-sized manikins, the new mask had significantly less leakage than one brand of mask, and delivered more tidal volume than the other (LOE 4). Palme et al tested five brands of face mask for leakage while ventilating newborn infants. They found that a round mask made of soft silicon rubber made the best seal (LOE 3b).

Cummin et al (1986) criticized previous research as being seriously flawed. They noted that subjects in those studies were not given any opportunity to practice prior to being tested, and that the tests consisted of one trial of just a few ventilations. Cummin and associates assessed the ability of EMTs to ventilate adult-sized manikins, after designing a study that they believed addressed these perceived flaws. The average subject had over six years of experience, responded to greater than seven cardiac arrests per year, and provided the ventilations in more than half of those resuscitation attempts. Results showed that 77% of EMTs were successful at meeting the target volume of 800 ml. during mouth-to-mask ventilation. After being given a chance to practice, 67% of EMTs were successful when using the one-rescuer BVM method, which is significantly higher than previous studies. The EMTs employed a variation in BVM technique, using their knees to stabilize the victim's head, while simultaneously pressing down on the mask, opening the airway, compressing the bag against their thigh, and squeezing it with one hand (LOE 4).

Terndrup et al (1989) compared a variety of ventilation techniques using paramedics and infant-sized manikins. They found that the subjects could deliver comparable tidal volumes while using mouth-to-mouth resuscitation, mouth-to-mask with an infant-sized resuscitation mask, and infant, child, and adult-sized BVMs. With BVM ventilations, mask fit appeared to be a more important factor than bag size. When using the adult-sized Laerdal Pocket Mask ™, there was significant leakage from poor mask fit, and adequate ventilation was not achieved (LOE 4).

Johannigman et al (1991) conducted a study using an adult-sized manikin with adjustable lung compliance. Peak airway pressure, tidal volume, and gastric insufflation volume were all recorded. Paramedics ventilated the manikin using the mouth-to-mouth, mouth-to-mask, and one-rescuer BVM techniques. With normal compliance, the subjects were able to ventilate successfully with all the methods. Some gastric insufflation occurred with both mouth-to-mouth and mouth-to-mask ventilation, but not with the BVM. As compliance was decreased, tidal volumes fell and gastric insufflation increased for all methods. Mouth-to-mouth ventilations consistently produced the highest peak airway pressures, tidal volumes and gastric insufflation, and BVM the lowest. Ultimately, when compliance was at its lowest level, rescuers were unable to deliver adequate tidal volumes with the BVM (LOE 4).

Greenslade (1991) studied various methods of ventilating adult-sized manikins during one-rescuer CPR, including a trial in a moving ambulance. Use of the mouth-to-mouth, mouth-to-mask, BVM, and automatic ventilator techniques were compared. The author found that the mouth-to-mouth and mouth-to-mask methods were equivalent, and superior to the use of the BVM or automatic ventilators. During the ambulance trial, an unexpected difficulty with using the BVM occurred. When the operators set the BVM down in order to perform chest compressions, it frequently fell on the floor because of vehicle motion. The operators had to interrupt CPR to recover it (LOE 4).

Cydulka et al (1991) examined 17 different barrier devices used for expired air ventilation to determine how effectively they protected the operator against potential contamination from the victim. First, each device was disinfected. Next, the operator sealed it to his own face, while breathing through it for one minute. Immediately afterwards, the rescuer side of the device was cultured for aerobic bacteria. All mask devices with one-way valves remained uncontaminated. Several limitations diminish the usefulness of the results. First, the researchers did not test for anaerobic bacteria or viruses. In addition, the brief trial simulating ventilations may not accurately reflect barrier performance during actual resuscitations. Nevertheless, the study showed that barrier devices with one-way valves have the potential of protecting the rescuer's side of the device from microbes in the victim's expired air. (LOE 4)

Terndrup and Warner (1992) compared mouth-to-mouth, mouth-to-mask, and one-rescuer BVM ventilation, using both adult and pediatric sizes of BVM, when performed by basic EMTs on infant-sized manikins. They found that each method produced adequate ventilations. However, both adult and pediatric BVMs were associated with excessive peak airway pressure (LOE 4).

Another adult-sized manikin study was conducted by Thomas et al (1992) to compare three methods of BVM ventilation. Rescuers alternated between the standard one-rescuer technique, where the bag is

squeezed with one hand, and an open palm variation where the bag was compressed between their hand and thigh or torso. The open palm method produced increased tidal volumes, which were significantly larger for rescuers with small hands. The two-rescuer BVM technique, with one rescuer opening the airway and sealing the mask with both hands, and the second rescuer squeezing the bag with two hands, was then performed. The two-rescuer technique produced much greater tidal volumes, in some cases twice as high, as either one-rescuer technique LOE 4).

In 1993, Thomas et al compared the mouth-to-mask and one-rescuer BVM methods while ventilating adult volunteers, after administering anesthesia, and before surgery. They found that both methods provided adequate ventilation, as evidenced by oxygen saturation and expired carbon dioxide monitoring. However, they noted increased airway pressure, greater gastric insufflation and lower inspired oxygen levels with the mouth-to-mask technique. This suggests that rescuers using the mouth-to-mask method need to be cautioned against delivering breaths with excessive force and volume (LOE 2b).

Brenner et al (1994) surveyed the medical staff of a 1200 bed hospital to determine attitudes towards administering mouth-to-mouth ventilations during an in-hospital emergency. Less than half of those surveyed indicated a willingness to use the mouth-to-mouth method under any circumstances. This number fell sharply when evidence of blood or infectious disease was present (LOE 3b).

In 1996, the authors (Brenner et al) followed up on this survey with a review of resuscitation attempts on adults that occurred outside of intensive care units. They found that only 37% of patients had ventilations initiated within one minute, and in 18% of the cases, they were delayed for over 3 minutes. In almost every case of delayed ventilation, the authors attributed the cause to be a result of the staff waiting for the arrival of a BVM. Every patient who received mouth-to-mask ventilation had care initiated in less than 3 minutes. In most of these cases, a resuscitation mask was readily available at the bedside. The two studies demonstrate the importance of having adjuncts for ventilation readily available (LOE 2c).

Hackman et al (1995) compared one and two-rescuer techniques of BVM ventilation on adult-sized manikins during CPR administered by fire fighter first responders. They found that when two rescuers operated the BVM and a third performed chest compression, ventilations were consistently of higher quality. They also observed that the overall CPR effort appeared to be superior. The rescuers maintained better hand position, and delivered compressions of greater depth. These results suggest that the technique they termed “three-rescuer CPR” may be more efficient and should be considered when sufficient personnel are available. (LOE 4).

Massawe et al (1996) compared mouth-to-mask and one-rescuer BVM ventilation during the resuscitation of newborn babies in two centers in India. They found that the response of the patients to resuscitation did not vary significantly between the two techniques. They did note that prolonged mouth-to-mask ventilation at a fast rate of 30 or more breaths per minute was exhausting to perform. This study was one of the few involving use of ventilatory devices that included outcome data. (LOE 2c).

Wheatley et al (1997) compared three different methods of BVM ventilation in volunteer adult patients undergoing general anesthesia prior to surgery. The conventional one-rescuer method, a modified open palm technique of bag compression, and the two-rescuer method were studied. The authors found that each technique delivered acceptable ventilation in most cases. However, they did find that two-rescuer ventilations produced higher airway pressures and greater tidal volumes (LOE 2b).

In 2005, Davidovic et al conducted a study that compared one and two-rescuer BVM ventilation on infant-sized and child-sized manikins. The subjects came from a variety of health care fields. Overall, the two-rescuer technique resulted in higher airway pressures and larger tidal volumes than the one-rescuer method. This study supported previous findings and provided data specific to the pediatric population (LOE 4).

Yildiz et al (2005) conducted another study of one-rescuer BVM ventilation on volunteer adult patients receiving anesthesia prior to surgery. The authors wanted to identify any characteristics that might predict which patients would prove difficult or impossible to ventilate by mask. Out of 576 patients, 7.8% were difficult to ventilate. They found that Mallampati Class 4, male patients, those who snore, are older, or overweight had a higher incidence of this difficulty. The participants of this study were practicing anesthesiologists, and even they had difficulty ventilating one patient out of every 13. This suggests that one-rescuer BVM cannot be relied upon as the sole means of providing ventilations in an emergency (LOE 3b).

Kitagawa et al (2006) examined the ability of medical students to successfully ventilate infant-sized and child-sized manikins. The subjects used a BVM device with three brands of adult-sized masks, including the Laerdal Pocket Mask ™, which was not designed for this purpose. Fewer students were able to successfully ventilate the manikins with the Laerdal device than with the other two brands. While limited in applicability, the results do demonstrate the importance of using the correct sized equipment (LOE 4).

Paal et al (2006) studied the ability of rescuers who had not received any prior training in first aid to learn how to perform ventilations. The mouth-to-mouth, mouth-to-mask, and mouth-to-faceshield methods were taught to high school students during one class lasting 10 minutes. Following training, each student attempted to ventilate an adult-sized manikin using each method. The mouth-to-mask method produced the best tidal volumes, and the smallest amounts of gastric insufflation. Students had difficulty delivering appropriate volumes with each method, which the authors attributed to the short class time. Nevertheless, the results suggest that it is possible for rescuers with minimal training and experience to learn to use simple adjuncts in a reasonable amount of time (LOE 4).

**Discussion:**

A number of studies have examined the use of mouth-to-mask and bag-valve-mask (BVM) methods to provide ventilations in an emergency. Yet, serious issues concerning the safety, efficacy, and feasibility of these techniques remain unresolved. Many of the studies are very old and quite small. There is a heavy reliance on mechanical models such as manikins, or trials on healthy volunteers, so the results may not accurately demonstrate the effects these interventions have during actual resuscitation efforts.

In some studies, the subjects come from a mix of health care backgrounds, such as nursing, emergency medical services, and respiratory therapy. These trials then are actually comparisons of the ability of various health care education programs to prepare their respective students to provide emergency ventilation, rather than a comparison of the methods studied. Furthermore, in some cases, the subjects were students. The results may reflect their inexperience instead of any characteristics of the methods themselves.

In many of the studies, the subjects were not allowed any practice time prior to testing, the test period itself was very short, with only a few ventilations, and were limited to one trial at a single site. Successful ventilation was defined using tidal volumes which exceed current recommendations. Nevertheless, some general conclusions can be drawn based on the available information.

It is clear from the evidence that many rescuers are extremely reluctant to use mouth-to-mouth breathing to provide ventilations in an emergency. Therefore, an alternative method that the rescuer has confidence in must be readily available. Two of the most common devices in use today are the bag-valve-mask (BVM) resuscitator and the resuscitation mask, which is a barrier device for mouth-to-mask ventilation.

It is unknown whether exposure to the rescuer's expired air poses a risk of infection to the victim. The BVM provides ventilation without this exposure, which is one factor in its favor.

There is some evidence that the one-way valve in the resuscitation mask protects the rescuer's side of the device from potential exposure to infectious agents in the victim's expired air. In one laboratory study, all barriers with one-way valves avoided the colonization of the rescuer's side of the device with aerobic bacteria. It is not clear whether this protection would last throughout an average resuscitation attempt. Whether the devices would be effective barriers to anaerobic bacteria or viruses is unknown.

It must also be noted that the rescuer's side of the mask, including the inspiratory port on the one-way valve, is subject to contamination from other sources, such as splashing of body fluids. BVM devices do not require oral contact by the rescuer. Theoretically, they should provide greater protection of the rescuer from these sources.

Both the mouth-to-mask and bag-valve-mask devices exhaust the victim's expired air through the exhalation ports of their one-way valves into the atmosphere in the immediate vicinity of the rescuers providing ventilations. Filtering medium in the exhalation circuit would be necessary in order to limit exposure of the rescuers to any pathogens contained in the victim's exhaled breath. Alternatively, rescuers using a BVM could wear masks. The actual risk of exposure to rescuers is unknown. However, in the absence of effective filtering, the risk to rescuers appears to be equal regardless of which device is used.

Mouth-to-mask breathing has been shown to be effective when used to ventilate manikins, healthy volunteers, patients undergoing anesthesia prior to surgery, and infants with birth asphyxia. These studies suggest that it is easier for a rescuer to maintain an open airway and adequate mask seal with the mouth-to-mask method than the one-rescuer BVM technique. This has been attributed to the fact that, with the mouth-to-mask method, two hands are used for this purpose.

The studies consistently demonstrate that mouth-to-mask ventilations can deliver higher tidal volumes than one-rescuer BVM use. This increase in volume can be accompanied by increased airway pressure, and gastric insufflation. Rescuers using mouth-to-mask ventilations should be cautioned to avoid excessive ventilation volume

or pressure.

There are few outcome studies to demonstrate similar efficacy in victims of respiratory emergencies. One large study of newborn infants suffering from birth asphyxia showed equivalent results with the mouth-to-mask and one-rescuer BVM methods. The study also found that mouth-to-mask ventilation at the rapid rates recommended for small children and infants was very tiring to the operator.

It is important that the correct sized mask be used for ventilations. While BVM devices can be outfitted with a complete range of different mask sizes, most brands of resuscitation mask are only available in a single adult size. Studies have shown that this size is particularly ineffective when used to ventilate infant-sized manikins.

Some resuscitation masks are equipped with inlets to allow for administration of supplemental oxygen during resuscitation. This oxygen is diluted by the rescuer's expired air, so the concentration is significantly less (averaging 50%) than that of the BVM device (greater than 90%). Note that the role of supplemental oxygen in resuscitation was not examined in any of the studies reviewed.

Resuscitation masks are compact, and are easier for an individual to carry than bag-valve-mask resuscitators. This makes them especially useful for rescuers, such as lifeguards and security officers, who move around their service area on foot, and do not have immediate access to supplies from a kit or cabinet.

Numerous studies have demonstrated that single rescuers, especially those with limited opportunities to use the skill, have difficulty ventilating adult manikins with the one-rescuer BVM technique. This has been attributed to the need for a rescuer to simultaneously accomplish three separate tasks. First, they must open and maintain the airway. Next, they need to form an adequate seal between the mask and face. Finally, they have to deliver the necessary tidal volume by squeezing the bag with one hand. Some mask leak may be unavoidable. However, the more leakage that occurs, the greater the tidal volume that must be delivered to ensure adequate ventilation.

One study conducted on adults undergoing surgery found that even practicing anesthesiologists had difficulty ventilating about 8% of their patients while using the one-rescuer technique with a mask. The incidence of these difficulties during emergency resuscitation is unknown. Mask design and technique seems to influence the success rate.

Several manikin studies compared standard masks with a new variant, which consisted of a round semi-inflated cushion mounted to a flat, round, flexible disc (Seal Easy ®, by Respironics). This new design was more effective during one-rescuer ventilation.

Other researchers tested a variation of technique, where rescuers used an open palm to squeeze the bag against their thigh or torso. This method was especially helpful for rescuers with small hands. One group of authors reported a modified position for one- rescuer BVM use. The rescuers used their knees to stabilize the victim's head, while simultaneously pressing down on the mask, opening the airway, compressing the bag against their thigh, and squeezing it. This method did produce greater tidal volumes. However, it would only be useful when the patient is lying on the ground or floor.

There is insufficient evidence to support the recommendations of some researchers that BVM ventilation be replaced by the mouth-to-mask method during the initial phase of all resuscitation attempts.

However, multiple studies suggest that one-rescuer BVM use is a complex skill that can be difficult to perform, especially on adults. Single rescuers who perform BVM ventilations must be well trained, have frequent opportunities to perform the skill, and aware of the potential problems with airway maintenance, mask seal, and tidal volume delivery. They need to monitor the effectiveness of their efforts on a breath-by-breath basis, especially observing the victim for visible chest rise. They should to be prepared to change to an alternate technique, such as mouth-to-mask or two-rescuer BVM, if necessary.

Most studies have shown that rescuers can be effective at one-rescuer BVM ventilation of infant-sized and child-sized manikins, provided that the appropriately sized mask is used. This may be due to the relatively large hand of an adult rescuer sealing a smaller mask to a child's or infant's face, and the smaller tidal volumes that are required. One study suggested that a soft, round mask made of silicon rubber would provide the best seal in infants.

Another study clearly demonstrated the difficulty of BVM use during one-rescuer CPR, especially in a moving ambulance. Under these circumstances, it is simpler and faster to use a method, such as mouth-to-mask, that can be more easily performed from the victim's side. This minimizes the need to change position, and results in shorter interruptions in chest compressions.

Studies of two-rescuer BVM demonstrates that this technique is easier to learn and use than the one-rescuer technique, and can provide adequate tidal volumes. All rescuers who provide one-rescuer BVM ventilation should also be trained in the two-rescuer technique.

As with the mouth-to-mask method, the two-rescuer BVM technique allows one rescuer to use both hands to seal the mask and open the airway. With each method, the rescuer provides ventilations while observing for visible chest rise. The differences are the method of delivering ventilations and the number of rescuers required.

The two-rescuer BVM method may deliver adequate ventilation with less peak airway pressure and may lower the risk of excessive volume and gastric insufflation when compared with mouth-to-mask breathing. It also allows significantly higher concentrations of supplemental oxygen to be administered, and facilitates transportation of the victim requiring continued ventilations.

One manikin study compared two-rescuer with three-rescuer CPR, which was defined as two-rescuer BVM ventilations with a third rescuer performing chest compressions. The results indicated that the three-rescuer technique delivered greater tidal volumes. In addition, the timing and depth of compressions were superior. It may be that allowing each rescuer to focus on a single task facilitated more efficient CPR.

There is not enough evidence available to make a direct comparison between the mouth-to-mask and two-rescuer BVM methods in regards to learning or skill retention. It is unknown what prerequisite knowledge is necessary to master either skill. The appropriate length of time necessary for training in either the mouth-to-mask or two-rescuer BVM method has yet to be determined. None of the studies examined the issue of skill retention.

**Summary:**

A review of the available literature comparing mouth-to-mask and bag-valve-mask ventilation reveals that there are many unanswered questions regarding these potentially life-saving techniques. More research is needed. For example, the actual risk of infection while using either of these methods is unknown. Still, some conclusions can be drawn.

The mouth-to-mask method may be effective at delivering adequate tidal volumes, although with higher peak airway pressures and increased risk of excessive ventilation and gastric insufflation than two-rescuer bag-valve-mask use. This technique can also be more tiring for the rescuer to perform.

Mouth-to-mask ventilation may be easier to learn and perform than the one-rescuer BVM technique. When a single rescuer is required to perform both ventilations and compressions during one-rescuer CPR, the mouth-to-mask technique is simpler and faster, and results in shorter interruptions of chest compressions.

Most brands of resuscitation mask are available in one standard adult size. This size is particularly ineffective when used on infants. Bag-valve-mask devices are available in adult and pediatric versions, with a complete range of mask sizes.

One-rescuer bag-valve-mask ventilation is a complex skill, which is harder to learn and perform. In order to use this technique, the rescuer has to select the appropriate sized mask and bag. Using one hand, they need to open the victim's airway and form an adequate seal between the mask and face. Then, using the other hand, they have to deliver the necessary tidal volume by squeezing the bag with one hand, while observing the victim for visible chest rise. Many rescuers have difficulty performing this skill, especially on adults. Mask design and variations in technique influence the results.

The two-rescuer method of bag-valve-mask ventilation may facilitate making an adequate seal and delivering the necessary tidal volume, with less peak airway pressure and lower the risk of excessive ventilation and gastric insufflation than the mouth-to-mask technique. It also allows higher concentrations of supplemental oxygen and facilitates transportation of the victim. It may be an easier skill to learn and perform than the one-rescuer technique.

**Recommendations and Strength:**

**Standards:** There is insufficient evidence to support a treatment standard.

**Guidelines:** There is insufficient evidence to support a treatment guideline.

**Options:** A single rescuer providing ventilations should use the mouth-to-mask technique rather than the bag-valve-mask technique. (Class III)

Multiple rescuers providing ventilations may use the two-person bag-valve-mask technique if properly trained and experienced in this method. (Class III)

| Class | Description | Implication | Level of Evidence |
|---|---|---|---|
| I | Convincingly justifiable on scientific evidence alone. | Usually supports Standard | One or more Level 1 studies are present (with rare exceptions). Study results consistently positive and compelling |
| II | Reasonably justifiable by scientific evidence and strongly supported by expert opinion. | Usually supports Guideline but if volume of evidence is great enough and support from expert opinions is clear may support standard | Most evidence is supportive of guideline. Level 1 studies are absent, or inconsistent, or lack power. Generally higher levels of evidence. Results are consistently supportive of guideline. |
| III | Adequate scientific evidence is lacking but widely supported by available data and expert opinion. Based on | Usually supports Option. | Generally lower or intermediate levels of evidence. Generally, but not consistently results are supportive of opinion. |
| IV | No convincing scientific evidence available but supported by rational conjecture, expert opinion and/or non peer-reviewed publications | Usually does not support standard, guideline, or option. Statement may still me made which presents what data and opinion exists. In some cases and in conjunction with rational conjecture may support option. | Minimal evidence is available. Studies may be in progress. Results inconsistent, or contradictory. |

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