September 2021

Manual vs. Mechanical Ventilation in Prehospital Setting

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Summary

Even though bag-valve-mask system is one of the most common devices used to provide ventilation during transports, it has shown that is complicated, has variable results, makes it difficult to reach the standards in terms of tidal volume and respiratory rate, and may expose to overpressure and thoracic overinflation. Due to the variability in respiratory parameters and changes in hemodynamics during manual ventilation, mechanical ventilatory support with portable devices have become the preferred method for transporting patients in prehospital environments. Mechanical ventilators offer a safe alternative to manual ventilation and allow healthcare providers to deliver consistent care and controlled tidal volumes at a determined rate. Patients can benefit from early initiation of non-invasive treatment in prehospital setting to avoid intubation and to improve patient outcomes.

Airway management and ventilation assistance are some of the most important aspects when managing out-of-hospital medical emergencies[1,2]. They directly affect patients' potential for recovery, promote oxygenation, and may protect against aspiration depending on the approach. Optimal controlled ventilation is crucial to optimize inspiratory time, expiratory time, and airflow[3].

Numerous techniques and devices are available to deliver oxygen-enriched air to patients during resuscitation[4] and acute respiratory failure. Historically endotracheal intubation has been considered the gold standard for airway management. Nowadays, the primary objective in prehospital environments is to assure ventilation of the patient, invasively or non-invasively, during transport to an emergency department. Options for airway management and ventilatory support involve different levels of invasiveness and complexity that require different technologies and expertise[3].

Manual ventilation during transport

The bag-valve-mask (BVM) is one of the most common devices used to provide ventilation, although the American Heart Association (AHA) ranks BVM devices lower in preference than other ventilation methods, such as emergency and transport ventilators[3-5]. **BVM resuscitation makes it difficult to reach the standards** in terms of tidal volume (Vt) and respiratory rate (RR)[2,6,7] and may expose to overpressure and thoracic overinflation[8,9]. Ventilation rates during the on-field application of cardiopulmonary resuscitation (CPR) by well-trained emergency medical services (EMS) personnel are far in excess of those recommended[10].

The **AHA Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care** recommend ventilation rates of eight to ten breaths per minute or two ventilations every 30 compressions, and tidal volumes between 500-600 mL[11]. The recommendation is to deliver each **rescue ventilation over 1 s**, give a sufficient tidal volume (Vt) **to produce** a **visible chest rise**[6,11,12]. This given volume of ventilation is adequate for oxygenation and minimizes the risk of gastric inflation[12]. However, both the provider and observer cannot be certain of the amount of Vt delivered, because it varies depending on the operator and squeeze method. The Vt delivered by a standard manual resuscitator shows large variations despite being performed by well-trained EMS providers[3,10].

Moreover, **manual ventilation is not recommended to be performed by a single provider**[12,13]. It requires two hands: one hand to secure the air-cushioned face mask airtight[12,14] while holding the airway open and the other hand to squeeze the self-inflating bag. The use of a BVM is a difficult technique to master and requires both hands of **the person performing the ventilation** as well as full attention to ensure the efficacy of ventilation. It is difficult to grasp the mask to keep the airway open with one hand while squeezing the bag with the other hand[15]. One hand is used to carefully squeeze the bag to provide adequate Vt[13,16] and RR while being careful not to over pressurize thereby causing gastric insufflation or barotrauma. Because this task requires the entire attention of the person in charge of the ventilation, **a second person is needed to perform additional care tasks** such as administering medications.

Since it is difficult to provide a consistent RR during manual ventilation[2,13], bag-valve ventilation may have adverse clinical consequences[7,10]. Alterations in the patient's respiratory status and arterial blood gas values can occur[2,17]. The technique can result in **hyperventilation or hypoventilation**[2,8,13,18,19], and associated shifts in blood pH toward alkalosis or acidosis, respectively.

Dumont et al. findings indicate that hypocarbia due to hyperventilation[18] and hypercarbia as a result of hypoventilation following **traumatic brain injury** (TBI)[19-21] increase the risk of mortality; and normocarbia following TBI decreases the risk of in-hospital mortality. The authors propose that abnormal physiologic states of hypercarbia and hypocarbia may induce secondary injury by inducing suboptimal oxygenation of brain tissue during prehospital management. Because CO_2 arterial pressure might affect cerebral blood flow, both hypocapnia and hypercapnia should be avoided[2]. Adjustment of ventilation to achieve normocarbia can be facilitated by monitoring the end-tidal CO_2 during transport[3,22]. Normocarbia appears to decrease the risk of mortality by maintaining a normal physiologic state and minimizing secondary brain injury. Therefore, normoventilation in prehospital setting is critical[8].

In addition, the vast majority of patients with return of spontaneous circulation need assisted ventilation. Hypoxemia must be prevented, considering the evidence of harm after myocardial infarction and the possibility of increased neurological injury after **cardiac arrest**, it is recommended that the inspired oxygen concentration maintains arterial blood oxygen saturation in the range of 94–98%[22]. Moreover, during CPR the physiological consequences of hyperventilation[8] and of prolonged ventilation intervals result in a persistently positive intrathoracic pressure during the decompression phase, thereby decreasing cardiac preload and cardiac output and impeding right ventricular function. Increased Vt is also known to adversely affect cardiac output[9].

Accurate breath rates are difficult to maintain because delivering assisted ventilation, especially under frenzied environments[8] and difficult clinical conditions, alters time perception[13]. Successful mask ventilation should give a Vt of 6-8 mL/Kg of ideal body weight[4] and an upper limit pressure of 20-25 cmH_2O. Ensuring adequate ventilating pressures, to achieve therapeutic tidal volumes during manual ventilation, is also difficult. As mentioned before, **excessive pressures** can cause a decrease in cardiac preload[3,9,10], cardiac output and coronary perfusion in hemorrhagic shock and cardiac arrest; it can also cause secondary brain injury[2,3,20,21] and gastric insufflation[16,23,24]. Also, bag-valve ventilation may result in **lung injury**[25] suggesting an increased potential for **barotrauma**[2,13]. However, insufficient pressures can lead to inadequate ventilation and concomitant hypoxia and hypercapnia. Inappropriate mask ventilation in respiratory compromised patients is a medical emergency.

Tidal volumes must be large enough to assure oxygen delivery with positive-pressure ventilation; however, applying **high airway pressures** that exceed the lower esophageal sphincter pressure can force ventilating gas into the stomach[16]. **Gastric inflation** can elevate the diaphragm, restrict lung movement, and decrease respiratory system compliance[4]. It also increases the risk of regurgitation and aspiration of stomach contents[13], particularly in patients who received concurrent chest compressions for CPR, victims of drowning, and cases in which lower esophageal sphincter pressure dropped severely due to prolonged hypoxia.

Mechanical ventilation before arrival to the emergency department

Due to the variability in respiratory parameters and the possible deterioration of blood gases and changes in hemodynamics during BVM use[3,17], mechanical ventilation with **portable devices** have become the preferred method for transporting patients in prehospital environments[2,12,22]. In those situations, utilizing automated feedback control, even with noninvasive ventilation, is more efficacious and safer than manual ventilation[13].

In 2020, Fogarty et al.[13] explained that healthcare providers using emergency transport ventilators (ETV) control the inflation time, respiratory frequency and tidal volume limiting peak airway pressures, therefore can mitigate barotrauma and/or stomach inflation. **Prehospital noninvasive ventilation** (NIV) limits the pressures to safe ranges avoiding over pressurization and overdistension of the lungs. It utilizes positive end expiratory pressure (PEEP) during exhalation avoiding the collapse of diseased alveoli. Therefore, the main objective of mechanical ventilation is to maximize gas exchange, oxygen delivery to the lungs and elimination of CO_2. The authors state that NIV improves alveolar ventilation while employing lung protective ventilation (< 20 cmH_20).

In the prehospital setting the use of ETV should provide a stable minute ventilation and free up a caregiver to perform other tasks[4,13]. By using these devices, EMS personnel can avoid exceeding the opening pressure of the lower esophageal sphincter and introducing air into the stomach. In addition, **ETV provide accurate and precise tidal volumes.** Also important, the use of these devices frees EMS providers to turn their attention to other patient care issues, and improve the overall patient care[3]. Prehospital use of ETV in patients with acute respiratory failure results in a **fast and significant improvement of vital functions**[26] such as blood pressure, heart rate, breathing rate, and oxygenation. This stabilizing effect seems to be largely independent of the duration of the ventilatory support.

O-Two Medical Technologies Inc. has overcome the challenges of manual ventilation by introducing the SMART Bag® MO Bag-Valve-Mask Resuscitator; however, this BVM controls flow assisting the rescuer to deliver proper RR and Vt. It does not eliminate the variability on the squeeze method given by the operator specially under hectic environments and difficult clinical conditions that affect ventilation parameters inadvertently.

Avoiding adverse events during transport is the primary goal in providing a safe transport. While many transports are uneventful, sometimes the patient's condition deteriorates as a consequence of the underlying disease progression[3]. Patient monitoring is difficult during transport, due to noise, limited space for the caregivers, and low light. ETV could resolve most of these issues[17], portable ventilators let the rescuer focus on maintaining a mask seal, observing the patient and checking live-monitoring parameters, without having to worry about squeezing a BVM correctly. **All patients requiring emergency ventilation must be adequately monitored**[17], including continuous monitoring of end-tidal carbon dioxide concentrations[22]. During prolonged resuscitative efforts the use of ETV, pneumatically powered and time- or pressure-cycled, allows the EMS team to perform other tasks while providing adequate ventilation and oxygenation. Nonetheless, providers should always have a bag-mask device available for backup[12]. Ideally, as mentioned before, SMART Bag® MO Bag-Valve-Mask offers better manual ventilation. It provides consistent controlled ventilations, flowrate and airway pressure while almost completely eliminating the risks associated with conventional BVM ventilation.

In Canada, McLeod and collaborators[27] reviewed the effects of prehospital NIV on in-hospital mortality. The authors conducted the study in adults with severe respiratory distress, due to acute cardiogenic pulmonary edema (CPE), exacerbation of chronic obstructive pulmonary disease (COPD), asthma, or pneumonia. They compared prehospital NIV and standard care and described that **prehospital noninvasive positive-pressure ventilation reduces in-hospital mortality** and the need for invasive ventilation. The authors recommend that continuous positive airway pressure (CPAP) should be considered as first line intervention, because it is cheap and easy to implement in clinical practice.

Recently, Mario Hensel and colleagues[26] in Germany reported in a study that **early initiation of NIV is important for successful treatment of acute respiratory failure**. Patients can benefit from initiation of non-invasive treatment already in the prehospital setting to avoid intubation and to improve patient outcomes. An important concern regarding the prehospital NIV is the additional time required to establish the equipment and to adapt the NIV-mask to the face of the patient, when avoiding a significant leakage. However, the authors emphasized that the extra effort associated with a prolonged on-scene time is justified aiming to improve vital functions. Therefore, when the ambulance transport time is short, as in most metropolitan areas, **the prehospital application of NIV is justified even with short times from arrival at scene to hospital handover.**

Portable ventilators are becoming increasingly robust in capability, and their prehospital use is more widespread for out-of-hospital emergency transports. Portable mechanical ventilators are used in patients with acute respiratory failure or some respiratory compromise who need ventilatory support while transported. Around the world, prehospital use of ETV is largely variable, some countries limit their use to air medical transport and critical care transfer ambulances[28]. Other countries mandate the use of prehospital ETV for patients who require ventilation providing advanced medical care.

In that regard, in 2001 Wayne et al.[3] described concepts and application of prehospital ventilation and concluded: ***"providing a ventilator for every ambulance should be considered because alternate techniques for ventilation have proved inadequate."***

As previously explained, **mechanical ventilators offer a safe alternative to manual ventilation** and allow healthcare providers to deliver consistent and controlled tidal volumes at a determined rate with or without additional medications. ETV should provide battery power sufficient to finish the transport; full ventilatory support; controlled Vt and RR; stable Vt with lung compliance changes; a disconnect alarm; airway pressure monitoring; stable PEEP; and FiO_2 up to 1.0. Other desirable features for transport ventilators are: lightweight, and easy to use[3]; low gas consumption; easy to trigger;

both volume and/or pressure modes; adjustable FiO_2; and ability to operate from a 50 psi O_2 source[17].

Portable mechanical ventilators such as the **eSeries automatic transport ventilators** offered by O-Two Medical Technologies Inc.[29] provide controlled ventilation for resuscitation and patient transport. These electronically controlled, pneumatically powered devices give a range of ventilation solutions for all patient respiratory requirements during prehospital care. The eSeries ventilators are compact, lightweight, ideal for long transports with long battery operation time. They offer volume and/or pressure modes, continuous parameter monitoring, adjustable FiO_2 up to 1.0 and low gas consumption. eSeries transport ventilators ensure standardization of ventilation and adherence to international guidelines as they count with all necessary and desirable features for prehospital positive-pressure treatment.

In conclusion, ventilation assistance is an important aspect when managing out-of-hospital medical emergencies involving acute respiratory failure. Advantages of prehospital noninvasive positive-pressure ventilation are that it delivers consistent and controlled Vt and RR, it directly affects patients' potential for recovery, promote oxygenation, and may protect against aspiration; these benefits are difficult to achieve with BVM ventilation. In other words, optimal controlled ventilation is crucial since it allows consistent Vt, respiratory frequency, and limited airway pressures minimizing the risks of complications such as hyperventilation, barotrauma, gastric inflation and hypoventilation.

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