Bag-Valve-Mask Tidal Volume and Lung Protective Ventilation Strategies

Steve LeCroy, MA, CRT, EMTP

In 2017 the "Resuscitation Academy Blog" touched on a High-Performance CPR program (HP-CPR) that was developed by the Resuscitation Academy. The Academy offers a week-long training program developed from resuscitation protocols created by Seattle and King County. The program has the following performance measures:

1. Depth of chest compressions (2.0-2.4 inches for an adult)
2. Ventilation volume (300-400 mL per ventilation)
3. Decompression (allow the chest to 100% recoil)
4. Chest compression rate of 100-120 per minute

Measures 1, 3 & 4 are standard measurements supported by significant research. However, measurement number 2, ventilation volume, is less clear and creates controversy over what size manual resuscitator should be used with adult patients. Does it make sense to use the same volume for all adult patients? Do respiratory arrest patients get the same volume as cardiac arrest patients? Everyone seems to agree that the standard adult manual resuscitator (1500-1600 mL) is too big and is one of the leading causes of over-ventilation. To compound the bag size problem there is no consistency across manufacturers regarding bag description and bag size. For example, Mercury Medical's® Child bag is 501 mL while Ambu's® Spur® II pediatric bag is 683 mL (Ambu® does not offer a child bag).

The HP-CPR guidance document does not mention the size of the patient. The question then becomes does patient size matter? For example, if the patient weights 100 kgs (220 lbs) the tidal volume would still be 300 to 400 mL per ventilation. In contrast for the same patient the International Liaison Committee on Resuscitation (ILCOR) resuscitation guideline recommends 6-7 mL per/kg or 600 to 700 mL per ventilation. The weak link is using predicted body weight as the key measurement. Predicted body weight is based on the patient's height and gender, a practice that has been proven to be highly unreliable. I believe the lower tidal volume is based on implementing a Lung Protective Ventilation Strategy (LPVS) and to protect the airway by reducing gastric insufflation that may lead to vomiting and aspiration.

Lung Protective Ventilation Strategies

LPVS goes beyond just reducing the tidal volume. The mainstays for LPVS is (1) limit tidal volume to prevent volutrauma; (2) limit end-inspiratory (peak) pressure to prevent barotrauma; (3) provide adequate PEEP to keep alveoli open; (4) limit the oxygen percentage or FiO_2. The idea for Lung Protective ventilation was developed to prevent injury and increase oxygenation when a patient was placed on a ventilator. If LPVS is good for ventilators, then the same strategy should be used with a manual ventilator.

Captain Steven C LeCroy (Ret), MA, CRT, EMTP is the Director of EMS Sales at Mercury Medical Tel: 727-412-4153 Blog: https://lecroyemsvision.com/

Limiting Tidal Volume and Pulmonary Physiology

Low tidal volume and dead space

Dead space represents the volume of ventilated air that does not participate in gas exchange. Effective ventilation must provide adequate CO_2 removal and oxygen saturation while not exposing the patient to excessive airway pressures (barotrauma) or tidal volumes (volutrauma). If CO_2 is not removed efficiently it will convert to an acid lowering the patient's pH (acidosis). Patients that become acidotic have a higher mortality rate.

> "Maintaining adequate pH should be weighed against the need to provide safe MV (mechanical ventilation) settings and safe airway pressures."
>
> – Brian J. Wright, MD

Even though the above quote is regarding mechanical ventilation, I believe it also applies to manual ventilation.

A lower tidal volume may work for smaller patients or patients in a low cardiac output states such as when CPR is being performed but may be totally ineffective for patients in respiratory arrest with relatively normal cardiac output. There must be a balance between CO_2 production and elimination. Some medical conditions such as Acute Respiratory Distress Syndrome (ARDS), advanced COPD and pulmonary embolism can have an increase in dead space requiring greater minute volume (tidal volume X ventilation rate). If the tidal volume is fixed or limited the only option to increase minute volume is to increase the ventilation rate. Unfortunately, fast respiratory rates with small tidal volumes only impact the dead space and does not improve ventilation. In addition, higher rates reduce exhalation time causing the patient to stack breaths increasing auto PEEP. The higher the auto PEEP the harder it is to ventilate a patient. The clearance of CO_2 depends on the relationship between CO_2 production and alveolar ventilation. It's important to point out that the average adult has approximately 150 mL of dead space in their airway, using the HP-CPR numbers would only leave 150-250 mL of usable air for adult patients.

Reducing gastric insufflation

The volume of air used with a manual resuscitator is important but it's only part of the story. Clinicians must be aware of the increase in pressure when the bag is squeezed too rapidly. When providing ventilations with a mask, as opposed to an advanced airway, air can go either towards the lungs or towards the stomach. Under optimal conditions the air will enter the lungs most likely due to resistance in the esophagus caused by the closing of the lower sphincter muscle. However, the lower esophageal sphincter can open with a small amount of pressure (20-25 cmH_2O) resulting in gastric distention. It only takes a few breaths to fill the stomach and people tend to vomit when the stomach fills with air. Additionally, a distended stomach compresses the diaphragm making it more difficult to expand the lungs.

When it comes to manual ventilation the ideal manual resuscitator bag size is still a mystery. But here's what we do know:

1. 1500-1600 mL bag is too big
2. Lung Protective Ventilation Strategies improves patient outcomes
3. There is no consistency in bag sizes by manufacturer
4. Determining tidal volume by patient height and gender is a guess at best
5. Barotrauma and Volutrauma are bad
6. It's doubtful that one size bag will fit all adult patients
7. Manual resuscitator effectiveness relies on the skill of the user
8. Good ventilation depends on the relationship between CO_2 production and alveolar ventilation
9. ILCOR resuscitation guideline for ventilation recommends 6-7 mL per kg

Summary

In respect to the HP-CPR guideline of 300-400 mL ventilation volume, I have been unable to find any supporting research for a standard volume for all adults or a calculated tidal volume in the range of 3-4 mL/per kg. The American Heart Association still recommends a tidal volume of 6-7 mL/kg. Currently, a perfect solution does not exist when it comes to manual resuscitator bag size for adult patients. The best solution to safely ventilate (manually) the greatest portion of the adult population is a skilled provider using a 1000 mL bag (functional volume of 750 mL) that incorporates a manometer, PEEP valve and pressure pop-off.

References

1 Gu, Wei, and Chun-Sheng Li. "Ventilation Strategies during out-of-Hospital Cardiac Arrest: A Problem That Should Not Be Neglected." *Journal of Emergency and Critical Care Medicine*, vol. 1, no. 9, 2017, pp. 23–23., doi:10.21037/jeccm.2017.08.08.

2 Weingart, Scott D. "Managing Initial Mechanical Ventilation in the Emergency Department." *Annals of Emergency Medicine*, vol. 68, no. 5, 2016, pp. 614–617., doi:10.1016/j.annemergmed.2016.04.059.

3 Wright, Brian. *Lung-Protective Ventilation Strategies and Adjunctive* ...emcrit.org/wp-content/uploads/2014/11/Bri-Wright-ARDS-Lecture.pdf.

Improving Home COPD Monitoring…continued from page 45

COPD patients has been shown to significantly shorten the time each day for testing in patients at home, reduce patient fatigue, and increase adherence with testing. For patients undergoing serial measurements, it assures that measurements that don't meet ATS/ERS quality criteria are not accepted for a single measurement requirement and yet minimizes the number of attempts to assure meaningful data. It should be recommended by the ATS Pulmonary Function steering committee that Statistical Process Control should be the standard for home monitoring of patients with COPD if an effective monitoring program is the intended use of spirometers.

References

1. https://www.lung.org/lung-health-and-diseases/lung-disease-lookup/copd/learn-about-copd/how-serious-is-copd.html
2. https://www.healthline.com/health/copd/facts-statistics-infographic#1
3. https://www.who.int/news-room/fact-sheets/detail/chronic-obstructive-pulmonary-disease-(copd)
4. American Thoracic Society and European Respiratory Society (Eur Respir J, 2005, Vol 26, pp. 948-968. No. 5 in SERIES "ATS/ERS TASK FORCE: STANDARDISATION OF LUNG FUNCTION TESTING")
5. Marsteller JA, et. al. Statistical process control: Possible use to monitor and evaluate patient-centered medical home models. Agency for Healthcare Research and Quality 2013 https://pcmh.ahrq.gov/page/statistical-process-controlpossible-uses-monitor-and-evaluate-patient-centered-medical-home
6. Sirichana W, Patel MH, Taylor M, Tseng CH, Barjakterevic I, DLeerup EC, Cooper CB. Justification for statistical process control in daily home spirometry for COPD patients. European Respiratory Society (Poster) 2013