Managing Initial Mechanical Ventilation in the Emergency Department

Scott D. Weingart, MD*

*Corresponding Author. E-mail: scottweingart@gmail.com, Twitter: @emcrit.

0196-0644/$-see front matter

http://dx.doi.org/10.1016/j.annemergmed.2016.04.059

[Ann Emerg Med. 2016;■:1-4.]

INTRODUCTION

The ventilator lectures given to most fledgling emergency physicians are often so complex and abstruse that many simply resign themselves to mute dependence on the respiratory therapist's settings. I have been guilty of delivering lectures such as these in the past. This piece represents a hopeful departure from this complexity. Understanding 2 simple ventilator strategies, lung protective and obstructive, will give a good foundation and management base for the first few hours of an emergency department (ED) patient's care. The following recommendations, when not specifically referenced, are based on my practice because there is a dearth of trials analyzing most components of ventilator management.

LUNG PROTECTIVE STRATEGY

The lung protective strategy focuses on low-tidal-volume ventilation to reduce ventilator-associated lung injury such as barotrauma and volutrauma. It is appropriate for patients already demonstrating signs of acute lung injury and may also be used for any intubated patient to prevent disease state progression into acute lung injury.[1,2] This strategy should be chosen for any patient intubated in the ED who does not have obstructive disease (asthma or chronic obstructive pulmonary disease). The lung protective strategy is based on the ARDSNet ARMA study, which is one of the few ventilator trials to demonstrate a mortality benefit.[3] Despite these benefits, many ED patients are still not being managed with a protective strategy of ventilation.[4]

Mode

Volume-assist control has numerous advantages for critically ill ED patients, including availability on all ventilators. The mode also prevents patient fatigue by offering full respiratory support. In my ED, the theoretical benefits of other modes (primarily a perception of increased patient comfort) are outweighed by the safety and ease of volume-assist control.

Once the mode is selected, only 5 other settings must be chosen.

Tidal Volume Is for Alveolar Protection

Set the initial tidal volume to 8 mL/kg. This initial setting is appropriate for all intubated ED patients. The weight used is the patient's predicted body weight (based on patient's height) rather than actual body weight.

This lower volume takes into account decreased functional lung volume (ie, "baby lung"), caused by derecruited or shunted alveoli, in a patient with acute lung injury. In a critically ill patient without current acute lung injury, these small tidal volumes may minimize lung injury. The tidal volume may need to be further decreased as discussed below. This setting should not be changed to achieve $PaCO_2$ goals (with the exception of patients with severe metabolic acidosis).

Inspiratory Flow Rate Is for Patient Comfort

When we breathe, we inspire a large amount of gas at the beginning of the breath that tapers to a small amount toward the end. This is called a decelerating flow pattern. Although some newer ventilators allow this flow pattern while in the volume-assist control mode, most ED ventilators do not. Instead, they deliver a fixed inspiratory flow rate. Erring on the side of excess flow toward the end of the breath is more comfortable than inadequate flow at the beginning of the breath. An initial setting of 60 L/minute usually leads to adequate flow for patient comfort. If a patient looks like he or she is trying to inhale more gas at the beginning of an inspiration, this setting can be titrated up. Lack of attention to this setting may lead to an increased sedation or analgesia need but is unlikely to affect patient outcome.

Respiratory Rate Is for Titrating Ventilation

The goal $PaCO_2$ should be chosen according to the patient's illness and acid-base status. Once this value is determined, the only setting that should be used to achieve this goal is the respiratory rate. Respiratory rates as high as 30 to 40 breaths/min are acceptable to achieve $PaCO_2$ goals. An initial rate of 15 to 16 breaths/min should allow normocapnia in most patients. After 20 to 30 minutes, venous or arterial blood should be drawn for blood gas testing to allow further titration.[5]

End tidal CO_2 can be used as a spur to increase the respiratory rate if the $ETCO_2$ value is greater than the $PaCO_2$ goal; however, a low $ETCO_2$ level should not trigger a decreasing of the respiratory rate. Physiologic shunt, decreased cardiac output, and dead space may lead to $ETCO_2$ values that significantly underestimate the $PaCO_2$ (remember this rule: all we can say is the $PaCO_2$ is at least as high as the $ETCO_2$).

If $PaCO_2$ goals cannot be achieved with even rapid respiratory rates, one should consider permissive hypercapnia.

PEEP and FiO_2 Are for Titrating Oxygenation

When faced with a low SpO_2, one may think it seems intuitive to increase the FiO_2. Unfortunately, this strategy has only a short-lived effect. Once the FiO_2 reaches greater than 50%, any continuing hypoxemia is due to physiologic shunt.[6] The solution to this shunt is to increase mean airway pressure through Positive End-Expiratory Pressure (PEEP). The ARDSnet strategy guides clinicians to increase FiO_2 and PEEP in tandem to allow alveolar recruitment.

Immediately after intubation, decrease the FiO_2 to 30% to 40% and assign the patient a PEEP of 5 cm H_2O. Using the chart in Table 1, rapidly titrate to PEEP-FiO_2 combinations that result in an SpO_2 of 88% to 95%. Allowing patients to achieve a saturation of 100% exposes them to excess pressure and hyperoxia.

Often, the initial PEEP and FiO_2 settings used to achieve saturation goals will need to be titrated downward; eventually, progressive alveolar recruitment will result in a saturation of 100%. At this point, PEEP-FiO_2 combinations should be decreased according to Table 1. Downward titration should proceed at a slower pace than upward titration to avoid losing the hard-won alveolar recruitment.

Checking for Alveolar Safety

Immediately after intubation, and subsequently every 30 to 60 minutes, a plateau pressure should be checked. Whereas the peak pressure on a ventilator represents a combination of alveolar pressure and large airway and ventilator equipment resistance, the plateau pressure approximates the pressure on and in the alveoli. By pressing the inspiratory hold button on the ventilator at the end of a breath, the plateau pressure can be measured. It is crucial that the patient be adequately sedated in order not to resist this breath hold. If the plateau pressure is greater than or equal to 30 cm H_2O, there is the potential for alveolar injury.

The solution to this issue is to decrease the tidal volume by 1 mL/kg until a plateau pressure of less than 30 cm H_2O is achieved. Tidal volumes as low as 4 mL/kg are acceptable, although rarely necessary in the ED. In such cases, you will likely need to increase the respiratory rate to maintain $PaCO_2$ goals. If you have reached the limit of respiratory rate titration, the patient should be allowed to maintain permissive hypercapnia.

In patients who are already demonstrating established severe acute lung injury (PaO_2/FiO_2 <200 mm Hg), rapid titration of the tidal volume to 6 mL/kg should occur even if the plateau pressures are acceptable.[3]

OBSTRUCTIVE STRATEGY

Usually, the only patients who require diversion from the lung protective strategy outlined above are the asthmatic and chronic obstructive pulmonary disease patients experiencing bronchospasm. These obstructed patients will experience air trapping and barotrauma because they are unable to fully exhale when exposed to the rapid respiratory rates of the lung protective strategy.

The best ventilatory strategy in the obstructive patient is to avoid intubation altogether. These patients often respond to aggressive pharmacologic and noninvasive ventilatory strategies. If forced to intubate because of worsening mental status, be aware that the ventilator will often make the pulmonary situation worse rather than better.

The obstructive patient receiving ventilator treatment requires deep sedation during the first few hours of care. Paralysis is often unnecessary if deep sedation and analgesia are provided. If paralysis is used, the treatment should be short-lived. Intubation and mechanical ventilation should

Table 1. FiO_2 and PEEP scale from ARDSnet ARMA trial.

FiO_2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.0	1.0	1.0
PEEP	5	5	8	8	10	10	10	12	14	14	14	16	18	20	22	24

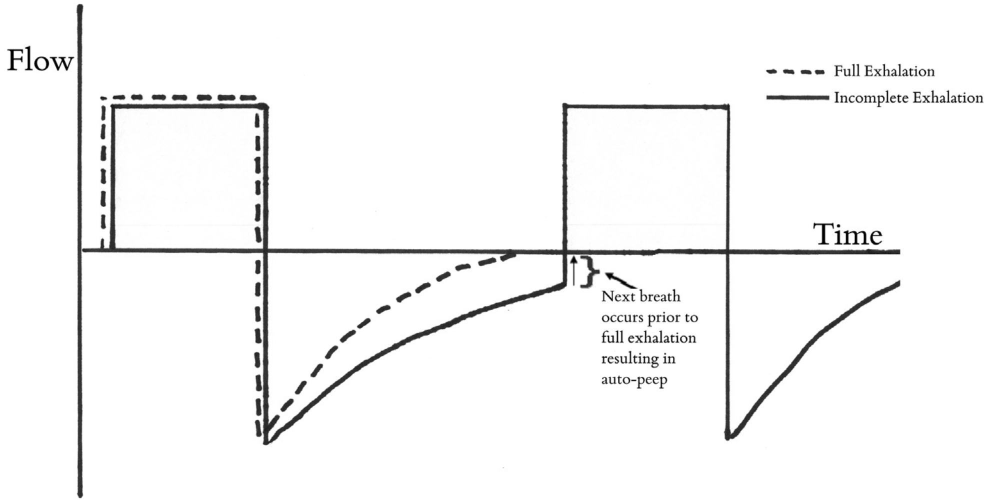

Figure. Flow versus time graph on the ventilator. The dotted line demonstrates a breath in a normal patient. The flow during expiration ceases and there is a period of no flow before the next breath (dotted line). In a bronchospastic patient, the next breath begins before full exhalation (solid line). This breath stacking must be corrected by decreasing the respiratory rate to avoid injurious auto-PEEP. As the patient's bronchospasm improves, his or her flow or time graph will begin to look like the normal patient's (dotted line); at this point, you may gradually up-titrate the respiratory rate.

not represent the end of the pharmacologic treatment of bronchospasm, but rather an opportunity to maximize these medication regimens.

The primary goal of the ventilator strategy for obstructive patients is to allow time to exhale. All settings are aligned to the aim of allowing a full exhalation after each ventilator breath.

Mode

Just as in the lung injury strategy, I select the volume-assist control mode. In my practice, any putative benefits of other modes have no applicability to the early stages of the postintubation period and are outweighed by the safety and familiarity of volume-assist control.

Tidal Volume

Use the same initial 8 mL/kg predicted body weight as for the lung injury strategy. This setting should not need to be titrated.

Flow

Some texts recommend increasing the inspiratory flow rate to decrease the time required for inhalation, in turn allowing a longer period for the subsequent exhalation. This will serve only to increase the peak pressure, causing unnecessary alarms without producing any clinically meaningful change in the expiration time.[7] A setting of 60 to 80 L/minute is more than enough flow for these patients.

Respiratory Rate Allows Time to Exhale

This is the primary titratable setting to safely manage the intubated patient with obstructive lung disease. Decreasing the respiratory rate allows more time for expiration. These patients will inevitably become hypercapnic when the respiratory rate is set properly. This hypercapnia should be permitted. A starting rate of 8 to 10 should be used and then titrated as discussed below.

PEEP and FiO_2

In isolated obstructive disease, patients receiving even a modicum of supplemental FiO_2 should not experience difficulty achieving adequate levels of oxygen saturation. An FiO_2 of 40% should allow an SpO_2 greater than 88%. Higher FiO_2 levels may be used when necessary.

There are no compelling data to suggest any benefit in the application of PEEP within the first few hours postintubation. Inappropriately high PEEP can be deleterious. As such, a PEEP of 0 is my recommendation when managing patients in the ED. Some resuscitationists' preferences may dictate setting low levels of PEEP ($\leq$5), but again there is no definitive evidence to support this practice.

Peak Pressure Alarm

Peak pressures represent resistance in an obstructive patient's large airways as a result of bronchospasm. Often, high peak pressures will be necessary to ventilate past this obstruction. These elevated pressures are not transmitted to the alveoli and thus convey no harm to the lung parenchyma. If the peak pressure alarm of the ventilator

Table 2. Summary table for the 2 ventilator strategies.

	Lung Protective Strategy	Obstructive Strategy
Mode	Volume assist control	Volume assist control
Tidal volume	Start at 8 mL/kg PBW; adjust for plateau pressure goal	8 mL/kg PBW
Inspiratory flow rate	Start at 60 L/min; adjust for comfort	60–80 L/min
Respiratory rate	Start at 16 breaths/min; adjust for $PaCO_2$ goal	Start at 10 breaths/min; adjust to allow full expiration
PEEP	Start at 5 cm H_2O; adjust according to table	0 cm H_2O (some may treat pt with PEEP $\leq$5 cm H_2O)
FiO_2	Start at 40%; adjust according to table	Start at 40%; adjust for SpO_2 $\geq$88%
Check for safety	Measure plateau pressure. If $\geq$30 cm H_2O, decrease tidal volume by 1 mL/kg	Measure plateau pressure or observe flow time graph. If plateau pressure $\geq$30 cm H_2O or flow/time graph shows incomplete expiration, decrease respiratory rate

PBW, Predicted body weight; *pt*, patient.

is set too low, the ventilator may terminate the breath prematurely, and the patient will receive little or no alveolar ventilation. To prevent this, increase the peak pressure alarm setting until the full breath of 8 mL/kg is allowed to be delivered. In obstructed patients, the peak pressure may be quite high, but the plateau pressure should remain well below the 30 cm H_2O (as long as the patient is being allowed to fully exhale), ensuring the safety of this strategy.

Checking for Safety and Further Titration

After initial settings, we must ensure that the patient has adequate time to exhale. This can be done in 2 ways: checking for full expiration on the flow or time graph or checking the plateau pressure.

Almost all modern ventilators have a flow versus time graph available. The Figure demonstrates how to ensure the absence of breath stacking, using this graph. Expiratory flow should return to baseline before the subsequent inspiration is initiated.

Alternatively, the plateau pressure measurement can be used. However, in the case of patients with obstructive lung disease, if the plateau pressure is elevated the problem is not excess tidal volume, but instead not enough time between breaths to allow full exhalation.

If the plateau pressure is greater than 30 cm H_2O or the flow graph demonstrates breath stacking, then the respiratory rate should be decreased to allow more time for exhalation. As the patient improves, the respiratory rate can be carefully up-titrated, with the provider guided by the safety checks just mentioned. A summary of the two aforementioned strategies can be found in Table 2.

CONCLUSION

The full complexity of ventilator management is best left to treatises of greater length than this one.[8,9] However, the practices described will provide a safe path through the initial stages of ventilator management. By taking over one of the primary physiologic processes of our patients, we shoulder an enormous responsibility. A meticulous approach to ventilator management will keep those we care for safe until they can recover.

Descriptions of the above strategies can be found on the EMCrit Podcast (http://emcrit.org/vent).

Supervising editor: Steven M. Green, MD

Author affiliations: From the Division of Emergency Critical Care, Department of Emergency Medicine, Stony Brook University Medical Center, Stony Brook, NY.

Funding and support: By *Annals* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see www.icmje.org). The author has stated that no such relationships exist.

REFERENCES

1. Sutherasan Y, Vargas M, Pelosi P. Protective mechanical ventilation in the non-injured lung: review and meta-analysis. *Crit Care*. 2014;18:211.
2. Needham DM, Colantuoni E, Mendez-Tellez PA, et al. Lung protective mechanical ventilation and two year survival in patients with acute lung injury: prospective cohort study. *BMJ*. 2012;344:e2124.
3. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. The Acute Respiratory Distress Syndrome Network. *N Engl J Med*. 2000;342:1301-1308.
4. Fuller BM, Mohr NM, Miller CN, et al. Mechanical ventilation and ARDS in the ED: a multicenter, observational, prospective, cross-sectional study. *Chest*. 2015;148:365-374.
5. Chiumello D, Coppola S, Froio S, et al. Time to reach a new steady state after changes of positive end expiratory pressure. *Intensive Care Med*. 2013;39:1377-1385.
6. West JB, Luks A. *West's Respiratory Physiology: The Essentials*. 10th ed. Dallas, TX: Wolters Kluwer; 2016.
7. Leatherman JW, McArthur C, Shapiro RS. Effect of prolongation of expiratory time on dynamic hyperinflation in mechanically ventilated patients with severe asthma. *Crit Care Med*. 2004;32:1542-1545.
8. Mosier JM, Hypes C, Joshi R, et al. Ventilator strategies and rescue therapies for management of acute respiratory failure in the emergency department. *Ann Emerg Med*. 2015;66:529-541.
9. Tobin MJ. *Principles and Practice of Mechanical Ventilation*. 3rd ed. Dallas, TX: McGraw-Hill Medical; 2013.