Intubating Asthma

Charles J. Blevins, MD

If a room full of emergency medicine physicians was asked, "How would you manage a severe asthmatic?" There would be a plethora of responses. However, all would likely agree that intubation is a last resort; something only to be considered when all other treatment options have been exhausted. Acute asthma exacerbations account for nearly two million ED visits annually and about 4% of these patients require ICU admission. Approximately one-third of those ICU admissions—roughly 27,000 patients—will require mechanical ventilation. Despite the complexity of initial management, outcomes for this subset of patients are reassuring. Unlike most other conditions that require mechanical ventilation, survival rates for intubated asthmatic patients range between 80-100%, with the majority of studies showing mortality rate <10%.[1,2] The scarcity, severity of illness, and reversibility of this condition dictate the routine rehearsal of management techniques, similar to procedures like pericardiocentesis or cricothyroidotomy.

The initial management of severe status asthmaticus should include some or ALL of the treatments in Table 1.[3,4] In addition, non-invasive ventilation (NIV), equally effective in lowering $PaCO_2$ in patients with severe hypercapnia, may be trialed. Still, up to 17% of patients receiving NIV will ultimately require intubation.[2] There exist countless algorithms for the management of the severe asthmatic; for the purposes of this discussion, we will skip straight to intubation.

Indications for intubation in the severe asthmatic include cyanosis, partial pressure of oxygen (PaO_2) less than 60 mmHg despite supplemental oxygen, bradycardia, persistent acidosis, altered or worsening level of consciousness, signs of exhaustion, paradoxical thoracoabdominal motion, a silent chest, and respiratory arrest. Worsening hypercapnia is also a factor to consider. $PaCO_2$ is expected to be low in a hyperventilating patient (<35 mmHg), and the presence of elevated or even normal $PaCO_2$ should be concerning for impending respiratory collapse.[1] However, a single result showing hypercapnia alone should not influence the decision for intubation.[5]

Preparation

Intubating the severe asthmatic can be extremely challenging, as risks include hypoxemia, worsening bronchospasm, pulmonary aspiration, tension pneumothorax, dynamic hyperinflation, hypotension, dysrhythmias, and even seizures. When managing these patients, you are truly between "a rock and a hard place." The respiratory acidosis created by increased dead space and hypoventilation will limit the functionality of both endogenous and exogenous catecholamines and can lead to cardiopulmonary collapse. Moreover, hyperinflation will decrease venous return, thus decreasing cardiac preload, which can also lead to arrest. A few pearls with regard to pre-intubation management are as follows: 1) maximize oxygenation early 2) consider pH 3) increase chance of first pass success 4) optimize induction, paralysis, and sedation.

Preparation for intubation should begin the moment you consider the necessity of managing an airway. In this incredibly sick population, that thought process often begins upon their arrival to the ED. Given their level of respiratory distress, these patients often present to the ED already on non-rebreather masks by EMS. However, it is important to note that many NRB's are not compatible with nebulized therapies, and the NRB is often replaced by a nebulizer mask. This is a reasonable practice, but one should consider adding supplemental nasal cannula oxygen or even

>>

Table 1[2,3]

Name	Dosing	Frequency; Notes
Supplemental Oxygen	2-6 L/min; Consider higher rate nasal cannula plus nebulized medications overtop via mask; may be difficult to give nebs via non-rebreather	Continuous; titrate oxygen saturation to 94-98%
Albuterol Nebulizer [ß-Agonist]	2.5-20 mg/hour depending on formulary (no study suggests higher dosing improves outcome; no study suggests higher dosing increases adverse events)	Continuous preferred over intermittent dosing (at least for the first hour)
Ipratropium Nebulizer [Anti-cholinergic]	0.5 mg diluted in 2.5 mL of saline	Every 20 mins (up to 3 doses), then every 8 hours
IV Magnesium	2-4 mg IV	Over 10-20 mins to avoid flushing and hypotension; may help protect against tachyarrhythmias associated with other treatments; more beneficial in pediatric patients
IV Steroids	1-2 mg/kg IV methylprednisolone equivalent	Every 6-8 hours; mainly delayed effects via immune modulation
SC ß-Agonists	Terbutaline 0.25 mg SC	Once; Specific ß-2 agonist
	Epinephrine 0.1-0.5 mg SC/IM	Once; Bridge to IV; ß-1 & ß-2
IV ß-Agonists	Epinephrine 1-4 mcg/min IV	Continuous
IV Ketamine	0.5-1 mg/kg dissociative dose	Once; can re-dose PRN

> **"AS WITH ALL CRITICAL CARE MEDICINE, NUANCE LOOMS LARGE; YET, WE WILL ATTEMPT TO GIVE INSIGHT INTO THE MOST ACCEPTED RECOMMENDATIONS."**

high-flow nasal cannula oxygen in conjunction with this nebulized mask. In the event of worsening status, pre-oxygenation will be key to a safe intubation and simultaneous use of NC or HFNC oxygen affords this preparation.[4]

Many of these patients will be physiologically hyperinflated and can demonstrate signs of early obstructive shock triggered by decreased venous return leading to decreased cardiac output. Additionally, they will often have severe respiratory acidosis. A common pressor like epinephrine, although part of the multi-modal treatment approach will have limited effect in an environment below a pH of 7.15-7.20. Thus, a pressor like vasopressin can be employed, as its action is not dependent on pH. Similarly, one could also consider pre-intubation dosing of an alkalinizing agent, like sodium bicarbonate in setting of severe acidosis. The efficacy of sodium bicarbonate administration is debated, and is thought to be limited in severe respiratory acidosis as the CO_2 produced readily crosses cell membranes, potentially leading to further decrease of intracellular pH.[2] This needs to be investigated further and, in the interim, administration in the face of severe acidemia is logical: acceleration of normal compensatory mechanisms (think renal production of bicarbonate), reduced respiratory drive (correcting the acidemia that further worsens tachypnea), and avoidance of worsening acidemia (preventing cardiac dysrhythmias, multiorgan failure).[5]

As with all critically ill intubations, it goes without saying that the rate of first pass success is directly correlated to decreased adverse events.[6] As such, the person intubating should be the physician with the most airway management experience. These airways should be planned with appropriate adjuncts as clinically indicated, including but not limited to video laryngoscopy, bougie, and supra-glottic devices like the LMA. Additionally, consider using the largest endotracheal tube (ETT) indicated for your patient. A larger ETT will reduce airflow resistance, facilitating ventilation, and will also aide in post-intubation procedures, like bronchoscopy. For most adults, an 8.0 ETT is appropriate (even 8.5 or 9.0 in taller patients).[1]

Lastly, remember that ventilator desynchrony and agitation will lead to higher peak pressures and volumes, increasing the risk of complications from hyperinflation. Deep sedation and paralysis are necessary at the initial phase of invasive ventilation given the marked activation of central respiratory drive by necessary management techniques of this condition; namely forced hypoventilation and hypercapnia.[3]

When selecting the appropriate induction agent for intubation, consensus recommendation includes ketamine or propofol, as both have bronchodilator properties. However, vasodilatory effects of propofol combined with blunting of sympathetic drive make it less desirable than ketamine, and it should be used with caution in these patients. If ketamine is not available, consider etomidate. Etomidate, although lacking bronchodilator properties, possesses favorable cardiovascular hemodynamic properties.[1]

Paralysis should be employed as part of the intubation strategy from the beginning, when the clinical scenario allows. Specifically, non-depolarizing agents like rocuronium are preferred as they will provide 30-60 minutes of paralysis, allowing for post-intubation monitoring and optimization as discussed below. If the airway is deemed difficult, or there is concern about failure, succinylcholine, a faster acting and cleared agent could be considered. After successful intubation, longer acting agents like vecuronium, rocuronium, or *cis*-atracurium can be utilized. When given, intermittent boluses are preferred to continuous infusion to allow for serial assessments and lessen risks of myopathy associated with prolonged paralysis.[2]

Although many of these patients exhibit significant improvement in first 24-48 hours on the ventilator, deep sedation is still recommended in the initial phase of mechanical ventilation, with a goal Richmond Agitation-Sedation Scale (RASS) score of -4 to -5.[3] Sedation agents should be selected carefully to avoid residual sedation effects that may prolong time on the ventilator. A combination of propofol and fentanyl is preferred to benzodiazepines and ketamine. Propofol, unlike benzodiazepines, has bronchodilator properties and allows for quick awakening.[2] Ketamine, although a recommended induction agent, is not recommended for long-term or continuous sedation.[3]

Initial Ventilator Settings

Many resources and podcasts have discussed this topic in the past few years, and there is a great deal of debate in the literature about ventilator management in these critically ill patients. As with all critical care medicine, nuance looms large; yet, we will attempt to give insight into the most accepted recommendations.

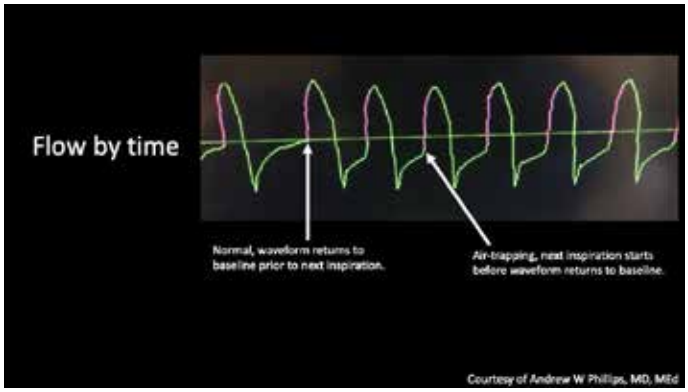
In mechanical ventilation, there are two main modes, pressure control and volume control. Although there has been no overall outcome difference demonstrated between volume control and pressure control modes,[1] volume control modes are often preferred in the severe asthmatic. Pressure control does have the advantage of achieving better control over alveolar pressure, limiting risks of barotrauma, but this comes at the expense of losing control over tidal volume, further worsening ventilation.[5] Conversely, volume control allows for control of tidal volume, and simultaneously allows for monitoring of peak inspiratory pressure (PIP) and plateau pressure (P_{plat}).[1] Additionally, volume control modes also allow for titration of how quickly a breath is delivered (inspiratory time, or "the slope"), unlike pressure control modes that are built to allow for patients to control their length of breath.[7] All of these factors contribute to the recommendation for volume control modes in the severe asthmatic.

>>

Tidal volume (TV) is more straightforward. We are accustomed to lung protective ventilation volumes of 6-8 cc/kg, as seen in ARDS, however, this is less of a concern in the asthmatic population, and a reasonable TV of 7-9 cc/kg is suggested. For most adults this is a TV of about 450-500 cc.

An oxygen saturation greater than 94% should be the oxygenation goal of the severe asthmatic; with an ideal range of 94-98%.[3] Rarely will a pure asthmatic require significant FiO2 to achieve this goal, and a reasonable number should be FiO2 around 40%. However, one would not be wrong to start the ventilator at 100% FiO2 and titrate down as tolerated; this depends on pre-oxygenation and post-intubation status.

Respiratory rate is arguably the most important parameter in intubated asthmatics. Status asthmaticus is a disease of obstruction, air trapping, and impaired ventilation. The main goal of intubation, in addition to alleviating fatigue and hypoxemia, is to control ventilation, and the respiratory rate is key. Not allowing for adequate expiratory time will result in "air trapping," also known as "breath-stacking" (Figure 1). This hyperinflation leads to decreased ventilation and increased risk of pneumothorax and arrest, among other complications.[1] A good place to start for RR is between 6 and 12 breaths per minute. Once set, it is necessary to monitor to the flow curve on the ventilator you are using (middle image in Figure 1). If the exhalation curve is not returning to baseline after a breath, then the respiratory rate should be reduced; as this is the definition of air trapping, breath stacking or auto-PEEP. Further monitoring parameters, PIP and P_{plat} will be discussed below.



Another parameter used to maximize exhalation time is the maximum inspiratory flow rate. Most ventilators have a maximum available peak inspiratory flow rate of 60-80 LPM. Choose 80 LPM to start, or have the respiratory therapist set the maximum allowed on your ventilator model. In a volume control mode, setting a higher inspiratory flow rate will decrease the inspiratory time to achieve the set volume, and thus increase/maximize the time for exhalation.[7] Additionally, shorten the ratio of inspiration to exhalation time (I:E ratio) to 1:3 or 1:4 to maximize exhalation time.

More complex is the discussion of positive end expiratory pressure. In mechanical ventilation there are two forms or PEEP, intrinsic positive end-expiratory pressure ($PEEP_i$) and extrinsic positive end-expiratory pressure ($PEEP_e$). $PEEP_i$ (intrinsic), also known as "auto-PEEP" is the pressure generated by hyperinflation or inadequate exhalation as described above: "air trapping" or "breath-stacking." This is in contrast to $PEEP_e$ which is the pressure maintained by the ventilator at end-expiration, serving to maintain recruitment of alveoli. In asthmatics, $PEEP_e$ has been shown to reduce mechanical work of breathing and improve respiratory effort, lung mechanics, ventilator triggering sensitivity, ventilation/perfusion mismatch, and gas exchange. However, for this discussion, we will assume that the patient is fully paralyzed and sedated. Thus, there is no benefit with regard to work of breathing by the addition of $PEEP_e$ since patient effort is not a variable. Moreover, the addition of $PEEP_e$ may actually worsen gas trapping, thus forming the recommendation to set $PEEP_e$ at zero in these patients.[1] Current practice favors lowering $PEEP_e$, but until further research provides more definitive answer, consider raising $PEEP_e$ for those patients in whom lowering $PEEP_e$ does not help.

In summary, the following initial ventilator settings can be considered when intubating the severe asthmatic:

- Mode: Volume Assist Control
- Tidal Volume: 7-9 cc/kg
- Respiratory Rate: 6-12 breaths/minute; start at 10 and adjust based on flow curve analysis
- Inspiratory Flow Rate: 60-80 LPM (set high in asthmatics)
- FiO2: start at 100% and titrate down for oxygen saturation 94-98% (expect to settle between 40-50%)
- PEEP: 0-3 cm H2O; start with 0 and adjust based on flow curve analysis, if this fails, consider raising $PEEP_e$ to help open airways
- Peak Pressure Alarm: set high to assure ventilator breath delivery

Ventilator Adjustments

Once the patient is intubated, frequent reassessment of ventilator mechanics and compliance is crucial. This is not the typical patient that can be left to "settle out" and reassessed in 20-30 minutes. The main complications in this patient population stem from hyperinflation. Dynamic hyperinflation begins when a reduction in expiratory flow results in incomplete exhalation of the delivered tidal volume. With subsequent breaths, lung volumes increase, leading to higher elastic recoil pressure and larger airway diameter. Multiple methods have been described to quantify hyperinflation, but the easiest method for the bedside clinician is measuring plateau pressure (P_{plat}) and peak inspiratory pressure (PIP) during volume-controlled ventilation.[2]

P_{plat} represents the average end-inspiratory alveolar pressure. In intubated asthmatic patients, the average P_{plat} is 24-26 cm H_2O. Given that the majority of patients with asthma have near-normal respiratory system compliance, P_{plat} is primarily influenced by the degree of

>>

hyperventilation.[2] The majority of published algorithms suggest an acceptable upper limit for P_{plat} of 30 cm H_2O. Even extremely high PIPs will not result in injury to alveoli (barotrauma) as long as P_{plat} is maintained less than 30 cm H_2O.[1] To measure P_{plat}, press the inspiratory pause button and hold it until the ventilator gives you a number. If P_{plat} is less than 30, the set RR is satisfactory, however, if it is greater than 30, you should decrease the RR.[7]

Consideration of PIP can provide insight into ventilator compliance for further optimization. When ventilating the severe asthmatic, it is expected to have severely elevated PIPs, sometimes as high as 60-80 cm H_2O. However, recall that asthma is a disease of medium-sized airways. These constrict, limiting air flow to and from the distal airways, so the alveoli never "see" the high PIP. However, many ventilators have default upper pressure limits around 40 cm H_2O. In this example, the ventilator would cease further flow when the pressure of 40 cm H_2O is reached, significantly limiting ventilation and worsening the patient's respiratory status. Thus, it is critical to set the upper pressure limit on the ventilator above the patient's average PIP, keeping in mind that PIP alone does not result in barotrauma.[1]

"INTUBATING THE SEVERE ASTHMATIC CAN BE EXTREMELY CHALLENGING, AS RISKS INCLUDE HYPOXEMIA, WORSENING BRONCHOSPASM, PULMONARY ASPIRATION, TENSION PNEUMOTHORAX, DYNAMIC HYPERINFLATION, HYPOTENSION, DYSRHYTHMIAS, AND EVEN SEIZURES."

Next Steps after Intubation

In patients with severe asthma, the vicious cycle of airflow obstruction, air trapping, and impaired ventilation leads to hypercapnia; the average PCO_2 in these patients is 68 mmHg and the average pH is 7.18.[2] The solution to hypercapnia in normal patients would be to increase ventilation by increasing the respiratory rate, as described by the alveolar ventilation equation. However, increased respiratory rate is not an option in the mechanically ventilated severe asthmatic. Thus a strategy of permissive hypercapnia can be employed; provided the pH be corrected and be maintained above 7.2. Additionally, there must be no evidence of increased intracranial pressure.[1] Provided these conditions are met, intubated patients can tolerate high PCO2 (>40 mmHg) and low pH (<7.4) for many days until the lungs improve.[4]

Similarly, it is important to note that status asthmaticus will eventually resolve, but this may take as long as a few days. Once intubated continue to aggressively treat the underlying etiology by employing the multimodal approach discussed in Table 1. The ETT should be used as a conduit for continued ß-agonists. While intubation is the highest level of intervention that can be offered in the majority of emergency departments in the US today, there are many other interventions available in the ICU including inhaled anesthetics, bronchoscopy, and even extracorporeal membrane oxygenation (ECMO). However, many academic/larger centers continue to push the boundaries of ED care algorithms, and we will undoubtedly see the expansion of (ECMO) as a treatment option for these patients in the future. ●

References

1. Laher AE, Buchanan SK. Mechanically Ventilating the Severe Asthmatic. *J Intensive Care Med*. 2018 Sep;33(9):491-501. doi: 10.1177/0885066617740079. Epub 2017 Nov 5. PMID: 29105540.
2. Leatherman J. Mechanical ventilation for severe asthma. *Chest*. 2015 Jun;147(6):1671-1680. doi: 10.1378/chest.14-1733. PMID: 26033128.
3. Le Conte, P., Terzi, N., Mortamet, G. et al. Management of severe asthma exacerbation: guidelines from the Société Française de Médecine d'Urgence, the Société de Réanimation de Langue Française and the French Group for Pediatric Intensive Care and Emergencies. *Ann. Intensive Care* 9, 115 (2019). https://doi.org/10.1186/s13613-019-0584-x
4. Herbert, Mel, and Stuart Swadron. "The 'Crashing' Asthmatic." EMRAP: C3. Aug. 2016.
5. Farkas, Josh. "Asthma." EMCrit Project, 28 January. 2017, emcrit.org/ibcc/asthma/.
6. Sakles JC, Chiu S, Mosier J, Walker C, Stolz U. The importance of first pass success when performing orotracheal intubation in the emergency department. *Acad Emerg Med*. 2013 Jan;20(1):71-8. doi: 10.1111/acem.12055. PMID: 23574475; PMCID: PMC4530518.
7. Weingart, Scott, and Rob Orman. "Intubated Asthmatic." EMRAP: Critical Care Mailbag. June 2016.