

Status Asthmaticus

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- I. Definition: Status Asthmaticus is a life threatening form of asthma defined as “a condition in which a progressively worsening attack is unresponsive to the usual appropriate therapy with adrenergic drugs and that leads to pulmonary insufficiency.” The primary mechanical event in status asthmaticus is a progressive increase in airflow resistance. Mucous plugging and mucosal edema or inflammation are the major causes for the delayed recovery in status asthmaticus. The combination of hypoxia, hypercapnia, and acidosis, along with the mechanical effects of increased lung volumes may result in cardiovascular depression or cardiovascular arrest.

- II. Initial Evaluation: As for all patients, the initial evaluation should center around the “ABCs.” History taking and a more detailed examination can occur **after** you assure **adequate** airway, breathing, and circulation. This need only takes a few seconds to minutes, but is essential.
 - A. Airway: Can the patient maintain his/her airway? Is the mental status adequate to protect the airway?
 - B. Breathing: What is the degree of air exchange? Is the patient cyanotic?
 - C. Circulation: How is the perfusion? The pulses?

- III. History
 - A. Previous history of wheezing?
 - B. If known asthmatic, what are maintenance meds? Compliance? Time of last aerosol?
 - C. Previous office/clinic/ED visits?
 - D. Previous hospitalizations, intubations, last steroid course?
 - E. When did this exacerbation begin?
 - F. Precipitating factors?
 - G. General medical history, including any medications.

- IV. More detailed Physical Examination
 - A. Vital signs
 1. Temperature: fever may indicate URI, pneumonia, other source of infection
 2. Pulse: Usually tachycardic, even before treatment
 3. Respiratory rate: Usually tachypneic.
 4. Blood pressure: Pulsus paradoxus over 10-15 correlates well with moderate to severe disease, as it indicates the effect that air trapping is having on the cardiac output. It is best measured with a sphygmomanometer and a stethoscope, and is the difference in systolic BP between the pressure at which an observer first hears faint pulse sounds and the pressure at which all sounds

are heard.

B. Breath sounds/Chest exam

1. There must be air movement in order to appreciate wheezing, lack of wheezing does NOT necessarily mean everything is fine!
2. I:E ratio is usually 5:2, may be up to 1:4 with a severe attack
3. Symmetry of breath sounds
 - a. Some asymmetry may be heard with asthma alone due to mucous plugging and atelectasis.
 - b. Increased wheezing unilaterally may indicate presence of a foreign body
 - c. Significantly decreased breath sounds unilaterally may indicate pneumonia or pneumothorax.
4. The use of accessory respiratory muscles (abdominal paradoxical breathing, sternocleidomastoid use, nasal flaring, intercostal retractions) correlates with the severity of airway obstruction. Wheezing is a less sensitive indicator of the degree of obstruction present.
5. Feel for the presence of crepitus in the neck or chest wall, signifying air leak and significant obstruction.

C. Cardiac exam

1. Attention should be paid to rate and blood pressure, including the presence of pulsus paradoxus. In addition, are the heart tones normal, is there a murmur (any evidence of pre-existing heart disease).

D. Mental status: Confusion or obtundation suggest significant hypercapnia or hypoxemia, and necessitate immediate action!!!

E. Clinical Asthma Score

	0	1	2
Cyanosis	none	Room Air (<94% SaO ₂)	in 40% (<94% SaO ₂)
Inspiratory Breath Sounds	none	unequal	decreased or absent
Accessory muscle use	none	moderate	maximal
Expiratory Wheeze	none	moderate	marked
Cerebral Function	normal	depressed or agitated	coma

V. Lab/Xray

A. Pulmonary function tests

B. Chest X-ray

1. A chest x-ray should be obtained on any patient with severe status asthmaticus in order to define the extent of the associated parenchymal disease, any evidence of extra-alveolar air (pneumothoraces, pneumomediastinum), and to

- differentiate other disease entities. Patients who have less severe disease may not require a CXR depending on presence or absence of other indications (ie, fever). Except in rare circumstances, any asthmatic deemed ill enough to warrant PICU admission should have at least an admission chest X-Ray.
2. The chest film of the asthmatic will usually show hyperinflation and streaky atelectasis.
 3. Infiltrates are frequently difficult to differentiate from atelectasis. Look for evidence of volume loss which will be present if there is significant atelectasis.
 4. If foreign body is suspected, perform inspiratory and expiratory films or bilateral decubitus films.
- C. EKG: The EKG may show right axis deviation, “p” pulmonale, and a right ventricular strain pattern, as the pulmonary vascular resistance is elevated in the presence of hyperinflation, hypercarbia, or hypoxemia. Not every pediatric asthmatic requires an ECG.
- D. Blood gases
1. Blood gases are not always indicated during an asthma exacerbation.
 2. A blood gas is indicated if:
 - a. You cannot determine the severity of the exacerbation
 - b. You believe the patient is worsening substantially and you want to quantitate the degree of worsening
 - c. Serial blood gases may be necessary to evaluate progression of disease if you feel the patient is difficult to evaluate clinically.
 - d. Do not obtain a blood gas if you aren’t going to act on the information, or if the information (ie, worsening or improvement) is available clinically.
 3. During an asthma exacerbation there is air trapping and ventilation/perfusion mismatch, resulting in hypoxemia. Initially compensation occurs and hyperventilation causes the PCO₂ to decrease. When further air trapping leads to decreased lung compliance and increased work of breathing, the PCO₂ will begin to increase. Thus, a “normal” pCO₂ in a wheezing patient is a sign of a moderately severe attack. The degree of hypoxemia is extremely variable and does not necessarily correlate with the overall severity of airway constriction.
 4. The presence of a metabolic acidosis (pH less than that predicted from pCO₂), accompanied by an anion gap suggests inadequate oxygen delivery, either due to impaired cardiac output or hypoxemia. It may occur due to the combined effects of hypoxemia, myocardial compromise, and the increased work of breathing and oxygen demand of the respiratory muscles.
 5. Capillary blood gases are adequate for evaluating pCO₂ if you are careful to assure good perfusion of the site used. Venous gases obtained from a peripheral vein are not useful at all.

VI. Differential Diagnosis of wheezing

- A. Bronchiolitis
- B. Pneumonia-viral, bacterial, atypical
- C. Congenital abnormalities: laryngotracheomalacia, vocal cord paralysis, tracheal or bronchial stenosis, gastro-esophageal reflux, vascular ring.
- D. Enlarged lymph nodes from infection or tumor
- E. Foreign bodies in trachea, bronchus, or esophagus
- F. Cystic Fibrosis
- G. Aspergillus
- H. Anaphylaxis
- I. Toxic fume exposure

VII. Treatment

PICU: If the patient does not respond to appropriate therapy in the emergency department, if the frequency of required aerosol treatments is greater than can be administered on the ward (usually q1 hour), or if the patient is deteriorating significantly despite appropriate therapy, he/she should be transferred/admitted to the PICU.

1. Monitoring
 - a. Continuous HR, RR, pulse oximetry
 - b. Frequent assessment of work of breathing and breath sounds by the bedside nurse, respiratory therapist, and the physician are **essential** for appropriate therapy and response to changes in patient status. The severe asthmatic truly requires team effort for optimal care.
 - c. An arterial line may be indicated if the attack is severe. It will allow for frequent blood gases, and more importantly, will provide real time monitoring of blood pressure in the event that the patient deteriorates and requires intubation. The time to put in the a-line is before you really need it, but most asthmatics can be managed without one. Again, frequent reassessment of the patient will be your guide to the need for arterial line placement.
2. Therapy: PICU therapy begins in step-wise fashion and escalates to a “kitchen sink” approach. This is because there is fairly little data which points to one combination of therapies being superior to others, and because an asthmatic deteriorating despite “usual” therapy is in significant danger.
 - a. **Standard** therapy includes steroids (solumedrol) and beta-agonists (intermittent aerosols, continuous aerosols, or intravenous terbutaline).
 - b. **“Adjunctive”** therapy includes anticholinergic agents (Atrovent)
 - c. Chest physiotherapy and/or IPV (intermittent percussive ventilation) may be helpful and/or necessary for some patients.
 - d. **“Kitchen sink”** therapies include magnesium, helium, ketamine, antibiotics, inhalational anesthetics, aerosolized lasix.

3. Pharmacology-alphabetical
 - a. **Albuterol-intermittent aerosol.**
 - b. **Albuterol-continuous aerosol**
 - i. Not an excuse for not continuously reassessing your patient.
 - ii. May be effective if intermittent aerosols are not, or may allow the patient to “rest.”
 - iii. Dose 0.5 mg/kg/hour.
 - iv. If delivered oxygen (10L) is insufficient to meet the demands of the patient, more O₂ can be provided with a nasal canula or extra O₂ y-
ed in at the mask.
 - c. **Other aerosolized beta-agonists:** occasionally a patient will fail to improve with albuterol, but will respond to another beta-agonist. Why this occurs is not clear. Other agents which can be used include terbutaline (0.5-1.0 mg/3ccNS) and isoproterenol (0.5 cc/3ccNS).
 - d. **Helium**
 - i. Helium is an inert gas with a density lower than oxygen or air. Helium reduces the resistance to airflow by increasing the proportion of laminar to turbulent flow.
 - ii. At least 60% helium is necessary in order to obtain meaningful improvement in gas density, and 70-80% is preferable. Thus, hypoxia may limit your ability to use helium. Attempting its use however is worthwhile, as occasionally a patient will improve to a degree that he requires significantly less oxygen when combined with helium than when breathing air/oxygen.
 - iii. Helium may be delivered via a non-rebreather mask or via the ventilator circuit for intubated asthmatics.
 - iv. There is some data to suggest that helium improves the deposition of inhaled particles to the distal bronchioles, hence may improve the distribution of inhaled beta-agonists when given concomitantly.
 - v. Beta-agonists can be delivered continuously via heliox. The aerosolization rate will be different, however, and the delivered dose of medication will be different (higher) if the concentration is not adjusted.
 - e. **Ipratropium bromide (Atrovent):** Anticholinergic agents are believed to work by blocking the irritant receptors and inhibiting cGMP metabolism, which results in bronchodilation. Ipratropium bromide is poorly absorbed and does not cross the blood-brain barrier, hence has fewer side effects than atropine. It is often an effective adjunct to beta-agonist therapy.
 - f. **Ketamine**
 - i. Ketamine is a dissociative anesthetic which has the useful property of producing bronchodilation.
 - ii. It produces less (**but not zero**) respiratory depression than most other anesthetics.

- iii. Ketamine produces increased sympathetic tone, hence generally there is preservation of blood pressure. It is an intrinsic myocardial depressant, however, so there may be myocardial depression if the patient sympathetic stores have been depleted.
 - iv. Other side effects include increased secretions and emergence phenomena (hallucinations upon emergence).
 - v. Ketamine is used most frequently for induction of anesthesia when intubating asthmatics. Occasionally it has been used, **with caution**, in unintubated asthmatics, for its bronchodilatory properties.
 - vi. Usual dose is 0.5-1.0 mg/kg. Continuous infusion 0.5-1.0 mg/kg/hour, titrated carefully to effect (sedation and bronchodilation).
- g. **Inhalational Anesthetic-Isoflurane**
- i. Can only be used for intubated asthmatics.
 - ii. Halothane and isoflurane produce smooth muscle relaxation and bronchodilation, along with hypotension. In the patient without a surgical stimulus, some pressor support is often necessary.
 - iii. Can be delivered with an anesthesia machine or a specially outfitted ventilator.
 - iv. Issues related to risk (hypotension in the patient, scavenging the gas from the environment) vs. benefit (bronchodilation) make its use somewhat controversial, and it is generally reserved for the most severe asthmatics.
- h. **Magnesium**
- i. Magnesium sulfate affects calcium metabolism and promotes smooth muscle relaxation.
 - ii. It has been shown to be effective in the treatment of acute, severe bronchospasm.
 - iii. Optimal dosing is unknown, however, the recommended dose is 25-100 mg/kg magnesium sulfate given over 20 minutes (generally 50 mg/kg). “Therapeutic” level is probably around 4 mg/dl. Monitor for hypotension during infusion.
- i. **Oxygen**
- Oxygen is a drug. It has benefits and complications associated with its use. Asthmatics are hypoxic due to ventilation-perfusion mismatch (V/Q mismatch). Supplemental oxygen can elevate the pO₂, but because of the shape of the oxy-hemoglobin dissociation curve, it may be difficult to reach full O₂ saturation if the V/Q mismatch is severe, and full saturation is not necessary. Oxygen is directly toxic to the lung in high concentrations (>50-60% for >24 hours), and can lead to resorption atelectasis (replaces nitrogen in the alveolus, oxygen is absorbed into the blood, and the alveolus collapses).
- j. **Terbutaline**-intravenous terbutaline has become widely used in treating the moderate to severe asthma exacerbation, in which frequent or

continuous aerosols have been ineffective, or which is especially severe on initial presentation. It is easily titrated and has a short half life if untoward side effects are encountered. It has almost entirely replaced isoproterenol for use in particularly severe asthmatics.

- i. Loading dose 10 **micrograms**/kg over 10 minutes.
 - ii. Maintenance dose-start at 0.4-1.0 **mcg**/kg/min. Increase the dose in increments of 0.2-0.4 mcg/kg/min, assessing for effect and side-effects. Dose can be titrated up quickly if the patient is not excessively tachycardiac. Maximum dose is unknown (probably 4 mcg/kg/min is "usual" maximum dose. It has been used in doses up to 20 mcg/kg/min rarely without adverse effect.)
 - iii. Side effects include tachycardia (most common), hyperglycemia, hypokalemia, worse hypoxia (due to increased V/Q mismatch with infusion), rhabdomyolysis. Monitor HR closely, watch for S-T changes if patient is severe and particularly tachycardic.
 - iv. The implications of elevated CPK levels in the asthmatic who does not have EKG changes are unclear. Occasionally there will be impressive elevations, almost always of the MM fraction.
 - v. There have been no controlled studies looking at the safety of combining intravenous terbutaline with theophylline. Generally we do not use both, as the tachycardia and resulting cardiac toxicity could theoretically be synergistic.
 - vi. Intravenous terbutaline can be used in combination with aerosolized beta agonists. Watch for excessive tachycardia. When the patient improves, wean the terbutaline before weaning the aerosols.
- k. **Theophylline:** The use of theophylline in the treatment of an acute asthma exacerbation has become controversial in recent years, as there is evidence that it is not helpful during an acute attack. There remain, however, some patients who are maintained on chronic theophylline or who respond particularly well to theophylline, in whom one might want to continue treatment during an acute exacerbation. One could either continue the oral theophylline preparation, or begin an aminophylline infusion.
- i. Loading dose 6-7 mg/kg
 - ii. Continuous infusion rate depends on patient age
 - iii. Therapeutic level 10-20 mg/l. Levels >20 are toxic, though some patients will display side effects (nausea, tachycardia, anxiety, jitteriness) at lower levels. Check levels after the bolus, at 4 hours, and at steady state (12-16 hours).
 - iv. Medications that **increase** theophylline metabolism (and thus **lower** the level): barbiturates, phenytoin, isoproterenol.
 - v. Medications that **decrease** theophylline metabolism (and thus **increase** the level): allopurinol, cimetidine, erythromycin, propranolol, oral contraceptives.

1. **Steroids:** All asthmatics in the PICU should receive steroids. The “standard” dose is 2-4 mg/kg/day methylprednisolone divided q6 following a “load” of 2 mg/kg. The mechanisms of action is multifactorial, and the onset of action is in the range of hours. Monitor patients for hyperglycemia and hypertension.
4. Intubation and Mechanical Ventilation
 - a. Indications: There are no widely agreed upon guidelines for when asthmatics require intubation. Intubation and mechanical ventilation are difficult and dangerous for the asthmatic, hence are avoided **if at all possible**. The difficulty arises as to when it is or is not possible.

Relative indications:

 - i. Apnea or “near apnea”
 - ii. Diminished level of consciousness with inability to protect the airway.
 - iii. Severe hypoxia despite supplemental O₂ via 100% non-rebreather mask. Look also for evidence of impaired O₂ delivery, i.e., presence or worsening of metabolic acidosis.
 - iv. Consider at slightly earlier time if the patient needs to be transported to another facility. Intubation in the back of an ambulance is always suboptimal. This decision requires careful judgement.
 - b. Complications: Pneumothorax (high airway pressures needed), cardiovascular compromise or collapse (more deleterious cardiopulmonary interactions) aspiration during intubation, worsening bronchospasm (presence of foreign body in trachea)
 - c. Induction and intubation: The induction and intubation of the severe asthmatic during a severe exacerbation is particularly difficult to do safely. The patient usually must be considered to have a “full stomach,” is NOT a candidate for an “awake” intubation due to the intense bronchospasm that will occur if he/she is not adequately anesthetized, and will be difficult to bag-mask ventilate due to the high airway pressures required. In addition they are hypercapnic, usually hypoxic, usually dehydrated, and there are potentially detrimental cardiopulmonary interactions occurring (the blood pressure will fall with intubation). A rapid sequence induction is generally indicated. Medications should include:
 - i. Lidocaine (to blunt the bronchospastic response to intubation) 1.5 mg/kg.
 - ii. Atropine 0.015 mg/kg
 - iii. Sedation-a combination of midazolam(0.05-0.1 mg/kg) and ketamine (0.5-1.5 mg/kg).
 - iv. Paralytic-succinylcholine (premedicate with defasciculating dose of pancuronium 0.01 mg/kg) 1.5-2 mg/kg, or rocuronium 1.2 mg/kg. If using succinylcholine, remember to give a long acting

- neuromuscular blocker immediately after intubation is achieved (risk of pneumothorax with positive pressure ventilation).
- v. Two functioning large bore IVs are essential. Start a fluid bolus as you are readying for intubation--additional preload will be necessary for adequate cardiac output after the patient is intubated.
- d. Mechanical ventilation: Ventilator management can be quite challenging. A few general principles:
- i. Do not try to normalize the pCO₂. Tolerate hypercapnia, and use pharmacologic buffering agents if necessary to increase the pH to >7.2. How high a pCO₂ you need to tolerate depends on the pressures needed to ventilate the patient.
 - ii. Try to keep plateau (alveolar) pressures <30-35 cm H₂O. Peak pressures may be higher than this due to increased airways resistance.
 - iii. Small tidal volumes are usually needed due to high resistance and propensity for air trapping. 5-7 cc/kg is a reasonable place to start.
 - iv. Rate should be low and expiratory time long, inspiratory time relatively short. The idea is to leave as much time as possible for expiration, without causing the inspiratory pressure to be too high because you are trying to get the gas in over too short a period. Rates of 10-14 and I:E ratios of 1:4 to 1:6 are typical.
 - v. Volume cycled or pressure cycled ventilation can be used. If using volume cycled ventilation, be sure to watch the pressures generated carefully. If using pressure cycled, the ventilator will usually not reach "plateau" or no flow, and you need to watch the volumes delivered. Frequent reassessment is crucial.
 - vi. If you encounter difficulty with oxygenation or just cannot move the chest, manually bag the patient and reassess therapy and ventilator strategy.
 - vii. There has been some success (case series and anecdote) with the use of pressure support ventilation in the sedated, but not paralysed, intubated asthmatic. Its routine use has not been subjected to controlled trials.
- e. The patient must be well sedated and usually paralyzed during mechanical ventilation. Continuous infusions or regularly scheduled doses should be used.
- f. Premedicate with extra sedation and lidocaine before suctioning to reduce the bronchoconstriction in response to stimulation.
- g. Continue aggressive bronchodilator therapy-aerosols or MDIs, intravenous terbutaline, atrovent, steroids. Consider "kitchen sink" therapies such as magnesium, ketamine, helium, isoflurane.
5. General management issues
- a. **Fluids/electrolytes.** The asthmatic admitted to the PICU for worsening respiratory distress must be kept NPO until such time as you are quite comfortable that he/she is improving, that the risk of deterioration

requiring intubation is past, and that the patient will be able to eat/drink and breathe at the same time. Until then, maintain hydration with IV fluids. You may see hyperglycemia or hypokalemia due to your therapy. Generally it is not of sufficient degree to warrant any additional therapy. Remember that with tachypnea the patient may have excessive fluid losses, or may have been dehydrated on admission due to poor PO intake when ill.

b. **GI prophylaxis:** The asthmatic in the PICU is usually on relatively large doses of steroids and is NPO. It is appropriate to treat with an H2 blocker or sucralfate/carafate.

c. **Antibiotics:** Use antibiotics if you suspect a bacterial pneumonia, sinusitis, otitis, or other bacterial infection as the cause of the patient's asthma exacerbation.

d. **Chest physiotherapy:** use during an acute simple asthma exacerbation is quite controversial. If used, you should evaluate your patient before and after treatments. PD often creates more wheezing immediately, but may be necessary if there is considerable atelectasis or mucous plugging.