Acute Asthma In The Pediatric Emergency Department

An 8-year-old boy is brought into your emergency department in the middle of the night with dyspnea. His mother states he has wheezed in the past, but he has been doing well since starting inhaled fluticasone. He only requires a few puffs of an albuterol metered-dose inhaler 2 or 3 times per week for relief. He has recently experienced coughing and a runny nose. The patient’s mother also admits that their family just started using a wood-burning stove. Tonight the patient developed increasing shortness of breath which could not be relieved by several puffs of albuterol. Otherwise, he is healthy. On examination, you notice that he is working hard to breathe with supravacuicular, intercostal, and subcostal retractions. On auscultation, his lungs have poor aeration without wheezing. He is breathing 48 times per minute, his heart rate is 140, and his O₂ saturation is 90%. How aggressive should you be with his treatment? What therapies would best treat his shortness of breath? What diagnostic studies does he require?

Asthma-related complaints are common triggers for emergency department visits. Asthma is a challenging disease since symptomatic patients often present to the emergency department without a known diagnosis of asthma, and the severity of their symptoms can vary widely from mild shortness of breath to fatal status asthmaticus. Prompt and appropriate intervention for patients experiencing asthma exacerbations can significantly improve morbidity and mortality. It can be a constant challenge to determine how to best manage patients presenting with worsening asthma symptoms and how to safely determine their dispositions. While acute management remains the focus of the emergency clinician, appropriate treatment of children with asthma can improve not only their short-term but their long-term outcomes as well.

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CME Objectives
Upon completion of this article, you should be able to:
1. Discuss the pathophysiologic changes in acute asthma exacerbations and how they relate to treatment.
2. Identify elements of the history and physical that will be helpful in assessing the child with an asthma exacerbation.
3. Review treatment options and adjunct therapies for acute asthma.

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The prevalence of asthma and the frequency of asthma-related emergency department visits are on the rise. The percentage of children with asthma has more than doubled since 1980. Asthma is now the most common chronic disease in childhood, and it affects nearly 9% of children, especially children under the age of 4. Children have a higher prevalence of asthma than adults and are more likely to have exacerbations. With improved management, asthma deaths among children are declining, but asthma still remains a burdensome source of morbidity, hospitalization, and missed school days.

Pediatric asthma is more common in males than females and is most prevalent among children of Puerto Rican or non-Hispanic black ancestry. In addition, it is more prevalent among children of lower socio-economic groups. Although asthma exacerbations occur year-round, a peak in exacerbations is apparent in early fall (September) in association with a return to school and a resurgence of viral respiratory tract infections. Other triggers include exposures to air pollution, tobacco smoke, environmental allergens such as dust mites or pets, exercise, emotional stress, and climate changes.

Asthma is best characterized as a chronic inflammatory disease with airway hyperresponsiveness and reversible bronchospasm. Individuals with asthma often have intrinsic airway hyperresponsiveness which can be induced by triggers such as viruses. Asthma exacerbations include an early bronchospastic phase during which patients generally respond well to bronchodilator therapy and a later inflammatory phase resulting from an inappropriate immune response. Early bronchospasm, if not resolved, induces mucosal edema and mucus secretion, increases smooth muscle tone, and results in airway narrowing. In the later inflammatory phase, the lung is infiltrated with inflammatory cells, and anti-inflammatory therapy is required in conjunction with bronchodilator therapy. Determining which phase a patient is experiencing can help to drive initial therapy as well as the expected response to and duration of therapy. Inadequate anti-inflammatory therapy for asthma can lead to irreversible remodeling including airway thickening and fibrosis as well as increased mucus secretion, thereby increasing airway hyperresponsiveness and obstruction. Emergency department clinicians are in a favorable position to facilitate adequate and timely treatment of asthma, not just acute exacerbations, which can improve the health of children with this chronic disease.

**Differential Diagnosis**

Cough, wheezing, and dyspnea are typical symptoms of an asthma exacerbation, but many other common and critical disease processes may resemble an asthma exacerbation. Even children with known asthma can have other causes for coughing, wheezing, and dyspnea; therefore, alternate diagnoses must always be considered. Both life-threatening (see Table 1) and non-life-threatening causes (see Table 2 on page 3) of asthma-like symptoms must be considered.

Bronchiolitis or other forms of viral-induced wheezing are common imitators of asthma in infants and young children and may be difficult to distinguish, particularly as upper respiratory viral infections are common triggers for asthma exacerbations. Prior to receiving their full set of immunizations, infants are at risk for pertussis. Older infants and young children may present with wheezing from an airway foreign body and may lack a history of ingestion. Congenital conditions such as tumors, hemangiomas, vascular rings, laryngomalacia/tracheomalacia, and vocal cord paralysis may also present in this age group, typically as progressively worsening wheezing or respiratory distress. Some infants may have failure to thrive secondary to their increased work of breathing. Wheezing may be a consequence of congestive heart failure from congenital heart disease, arrhythmias, or myocarditis. Retropharyngeal abscess may also present with wheezing in young children. These children usually present as acutely ill with fevers and decreased neck movement.

Older children and adolescents may present with wheezing from a variety of etiologies. Most commonly, infections such as viral or bacterial pneumonia will present with wheezing. Inflammatory processes such as hypersensitivity pneumonitis, vasculitis, or collagen vascular disease can also present among older children. Vocal cord dysfunction, psychogenic cough, and panic attack are common causes of apparent respiratory distress and are diagnoses of exclusion. Pulmonary manifestations of cystic fibrosis and alpha 1-antitrypsin deficiency may also develop within this category.

**Table 1: Acutely Life-Threatening Diagnoses That May Mimic Asthma**

<table>
<thead>
<tr>
<th>Diagnosis</th>
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<tbody>
<tr>
<td>Anaphylaxis</td>
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<tr>
<td>Airway foreign body</td>
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<tr>
<td>Pneumonia</td>
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<tr>
<td>Pertussis</td>
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<tr>
<td>Congestive heart failure</td>
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<tr>
<td>Supraventricular tachycardia</td>
</tr>
<tr>
<td>Airway tumor/hemangiomatoma</td>
</tr>
<tr>
<td>Chest mass</td>
</tr>
<tr>
<td>Retropharyngeal abscess</td>
</tr>
<tr>
<td>Hypersensitivity pneumonitis</td>
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<tr>
<td>Pulmonary embolism</td>
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<tr>
<td>Vasculitis (Churg-Strauss, Wegener's granulomatosis)</td>
</tr>
<tr>
<td>Collagen vascular disease (SLE, sarcoid)</td>
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</tbody>
</table>

The percentage of children with asthma is apparent in early fall (September) in association with a return to school and a resurgence of viral respiratory tract infections. Other triggers include exposures to air pollution, tobacco smoke, environmental allergens such as dust mites or pets, exercise, emotional stress, and climate changes.

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age group. Anaphylaxis must also be considered as it can present at any age.

### Prehospital Care

The goals of prehospital care for the child experiencing an asthma exacerbation must include timely assessment and recognition of the severity of the exacerbation and initiation of appropriate treatment. A patient’s history of severe asthma, including previous intensive care admissions and intubations as well as physical examination including general appearance, vital signs, mental status, and ability to speak normally, can assist the prehospital provider in patient assessment; although, none of these alone can reliably gauge the severity of a patient’s exacerbation. A child’s work of breathing evaluation, including mental status, respiratory rate, and accessory muscle use, are keys to appropriately assessing their severity of exacerbation. The presence of wheezing on auscultation is an important physical finding, but the absence of wheezing in very severe asthma exacerbations may be misleading.

Inhaled beta agonists such as albuterol are first-line therapies for asthma exacerbations. They may be administered intermittently or continuously, and their safety profile is well established in the prehospital setting. Inhaled anticholinergic agents such as ipratropium are also helpful in moderate-to-severe acute asthma and may be added to inhaled beta agonists for co-administration. Corticosteroids, although a mainstay of asthma therapy, require hours to be effective and are unlikely to benefit the patient in a prehospital setting. Patients in extremis may benefit from subcutaneous epinephrine or terbutaline, and intravenous magnesium may be considered in severe cases. Noninvasive ventilation may be helpful in avoiding mechanical ventilation, which is used only as a last resort in patients with respiratory failure. Significant regional variability exists with regards to the scope of prehospital personnel practice.

### ED Evaluation

A patient’s history is essential in assessing the severity of his or her underlying disease as well as the current exacerbation. The duration of symptoms as well as any prodrome are helpful in determining whether a child is in the earlier bronchospastic phase or the later inflammatory phase of the exacerbation, which may require extensive and prolonged therapy. In addition, the use (or failure of use) of home medications can be beneficial in determining compliance and the baseline control of the patient’s asthma as well as the patient’s perceived severity of the exacerbation. However, many children may be too young to reliably verbalize their symptoms, so reliance on patients’ assessments of their exacerbations can be misleading. Patients who use rescue medications more than 2 times per week, experience night-time symptoms more than 2 times per month, or refill their rescue medications more than 2 times per year may be inadequately controlled. Recent increased use of rescue bronchodilators is a marker for increasing disease severity. It can be helpful to ask parents about appropriate use of rescue medications as well, ensuring parents are using spacers with metered-dose inhalers (MDIs) to optimize pulmonary deposition of medication. Ask patients about exposures to triggers such as upper respiratory viral infections, pets, smoke, environmental allergens, emotional stress, or exercise. If a patient previously required admission to the hospital, particularly to the intensive care unit, he or she is more likely to require subsequent admissions. The number of ED visits, the last systemic steroid burst, and the total number of steroid bursts within the last year can also help gauge the underlying level of control as well as the severity of a patient’s disease.

Even patients diagnosed with mild asthma can be at risk for life-threatening exacerbations. Markers for severe exacerbations include doubling of beta agonist usage or an increased usage of 1 MDI canister per month. Although young children are more likely to be diagnosed with asthma, adolescents and non-Hispanic blacks are more likely to suffer fatal or near-fatal exacerbations. Children presenting with life-threatening asthma exacerbations are also more likely to have been previously admitted, particularly within the last year. Other risk factors include admission to the intensive care unit, additional ED visits within the last year, O₂ saturations < 91%, and a longer history of asthma. The physical examination is a key component of the assessment of acute asthma, and vital signs are an excellent place to start. Patients presenting with

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### Table 2: Non Acutely Life-Threatening Diagnoses That May Mimic Asthma

<table>
<thead>
<tr>
<th>Diagnosis</th>
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<tbody>
<tr>
<td>Bronchiolitis</td>
</tr>
<tr>
<td>Laryngomalacia/tracheomalacia/bronchomalacia</td>
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<tr>
<td>Vocal cord dysfunction</td>
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<tr>
<td>Vocal cord paralysis</td>
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<tr>
<td>Psychogenic cough</td>
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<tr>
<td>Panic attack/hyperventilation</td>
</tr>
<tr>
<td>Suppurative bronchitis</td>
</tr>
<tr>
<td>Primary ciliary dyskinesia</td>
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<tr>
<td>GERD</td>
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<tr>
<td>Vascular ring</td>
</tr>
<tr>
<td>Allergic bronchopulmonary aspergillosis</td>
</tr>
<tr>
<td>Alpha 1-antitrypsin deficiency</td>
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<tr>
<td>Cystic fibrosis</td>
</tr>
</tbody>
</table>

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*References not listed.*
For most patients, chest radiographs are not helpful in the emergent assessment of asthma. Children with acute asthma often have abnormal chest radiographs showing hyperinflation, hypoinflation, atelectasis, or increased extravascular fluid. These findings rarely affect patient management. Even among first-time wheezers, chest x-rays are generally not helpful. There is a small subset of patients for whom a chest x-ray may be helpful, including patients with fever, focal abnormalities on examination, or no family history of asthma. Chest x-rays may also be warranted (and could further direct therapy or trigger admission) in children who respond less favorably than expected to bronchodilator therapy. In patients with unilateral chest pain or differential wheezing, a chest radiograph is indicated to evaluate for pneumothorax or pneumomediastinum.

One objective and possibly underutilized assessment tool in acute asthma is measurement of peak expiratory flow. Ideally, patients with asthma use their peak flow meters at home to monitor their symptoms and know their personal best peak flows. If patients do not know their personal best, predicted values can be calculated based on a patient’s age, height, and gender. Patients with a peak flow above 70% of expected are classified as experiencing a mild exacerbation, a flow between 40% and 70% of expected is classified as a moderate exacerbation, and a flow below 40% of expected is classified as a severe exacerbation. Although not all patients are capable of performing a peak expiratory flow, many children above 6 years of age are able to reliably perform this skill, particularly if they use a peak flow meter at home. Both initial and follow-up measurements can be used to drive therapy in the emergency department and to objectively determine responses to these therapies.

### Treatment

Inhaled beta agonists have long been the initial drugs of choice in the treatment of acute asthma. The safety and efficacy of beta agonists in reversing bronchospasm have been well-established, although tremors, tachycardia, headache, and serum hypokalemia can occur. Albuterol, the most commonly used beta agonist, can be administered via nebulization or MDI with a spacer and is equally effective regardless of the modality used to deliver the drug. A dose of 0.15 to 0.3 mg/kg is recommended, up to 5 mg per treatment, although standard doses of 2.5 to 5 mg nebulized albuterol or 6 to 12 puffs of a MDI have been shown to be safe and effective. Albuterol should be administered up to 3 times per hour or until relief of bronchospasm has occurred. For severe asthmatics, continuous nebulization of albuterol (0.5 mg/kg/hour up to 15 mg/hour) is more effective than intermittent treatments and results in more rapid improvement and resolution of symptoms.

### Diagnostic Studies

Few diagnostic studies exist that are both feasible and helpful in the emergent assessment and treatment of asthma. In the acute care setting, asthma is primarily a clinical diagnosis, particularly in pediatrics. Laboratory evaluation of children experiencing an asthma exacerbation is generally not helpful. Pulse oximetry and clinical assessment of work of breathing are generally the best methods of patient assessment. Since no set values for pH, pCO₂, or pO₂ are diagnostic for respiratory failure, blood gases generally do not add to the clinical assessment of acute asthma. Most patients will have mild hypoxemia and respiratory alkalosis. However, blood gases can occasionally be helpful in the assessment of the acutely worsening asthma patient, particularly patients experiencing respiratory or metabolic acidosis.

For most patients, chest radiographs are not helpful in the emergent assessment of asthma. Patients with severe exacerbations also often have tachypnea, tachycardia, and pulsus paradoxus, although the presence of normal vital signs does not rule out a severe exacerbation. Distressed patients may use accessory muscle groups (including their abdominal muscles) to breathe, resulting in a paradoxical see-saw motion to the chest and abdomen. Retractions, particularly supraclavicular retractions, indicate a forced expiratory volume (FEV1) less than 50% of predicted and should alert the practitioner to more severe disease. On auscultation, expiratory wheeze or biphasic wheeze may be heard. The “silent chest,” signifying severe obstruction, is an ominous sign. Patients with agitation or depressed mental status may be approaching respiratory failure.

There are a variety of standardized tools for objectively measuring the severity of an asthma exacerbation and the response to therapy. Although many have passed tests of validity, the practical utility in the emergency department setting has not been well established, and no one score is widely accepted as standard in pediatric asthma assessment. Most asthma scoring systems include objective features such as oxygen saturations, respiratory rate, and heart rate and also by necessity include subjective items such as wheezing, accessory muscle use, and inspiratory:expiratory (I:E) ratios. Consistent use of an asthma score by all providers may help to standardize care within a department, but a widely accepted scoring system has not yet been adopted.

The Pulmonary Score, Pediatric Asthma Severity Score (PASS), and Pediatric Respiratory Assessment Measure (PRAM) are commonly used asthma scoring systems that are easily employed.

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fewer hospitalizations. In addition, continuous treatments are less labor intensive than multiple intermittent doses and may be more cost-effective. A drawback to continuous therapy is that patients may be assessed less frequently, side effects such as tachycardia and jitteriness are more pronounced, and hypokalemia may develop. Oral albuterol has not been shown to be effective in acute or chronic asthma management.

Levalbuterol is another drug recently approved by the FDA for use as an inhaled beta agonist. Whereas racemic albuterol is a 50:50 mix of R and S albuterol, levalbuterol is the pure R-enantiomer. In vitro studies have raised theoretical concerns about deleterious effects of the S-enantiomer component of albuterol including increased airway reactivity.

Levalbuterol is administered via nebulization or MDI and has been shown to be as effective as albuterol in relieving bronchospasm. Clinical studies have failed to show a benefit of levalbuterol over racemic albuterol in acute asthma exacerbations. A study by Carl et al showed decreased hospitalization rates for children treated with levalbuterol, but objective data on pulmonary function was not reported, and the admission rate of 45% for children receiving albuterol was higher than that seen in most pediatric emergency departments. Other studies have not shown a difference in hospitalization or ED length of stay for children treated with racemic albuterol versus levalbuterol.

Some studies show a modest decrease in tachycardia with levalbuterol, but no differences for other side effects including tremor, vomiting, palpitations, or nervousness have been shown. At nearly 5 times the cost, it appears the benefits of levalbuterol do not outweigh the significantly higher cost for most pediatric patients.

Anticholinergics such as ipratropium have been shown to be beneficial in the setting of acute asthma. Ipratropium works by blocking cholinergic receptors and reducing bronchoconstriction. Although not effective for patients with mild-to-moderate exacerbations as monotherapy, ipratropium co-administered with beta agonists can improve lung function and reduce hospitalization rates in children with severe exacerbations. Two or 3 doses of 250 to 500 mcg are typically added to an inhaled beta agonist and administered every 20 to 30 minutes and later as needed.

Ipratropium has only been shown to be effective in the acute setting. Studies of hospitalized children have failed to show any benefit to the addition of ipratropium to their treatment regimens.

Epinephrine is another beta agonist which may be useful for asthma exacerbations. Although the literature in pediatrics is less clear for epinephrine compared to albuterol, nebulized epinephrine has been used for years in upper airway obstructive conditions such as croup. In addition to its tis-
sue vasoconstrictor effects, epinephrine may also decrease mucous production and is an effective bronchodilator and pulmonary vasodilator, which may result in a transient V/Q mismatch. Nebulized racemic epinephrine (0.03 mL/kg) has been shown to be as effective and as safe as albuterol, but the incidence of minor side effects such as nasal discharge or cough is increased with epinephrine.

Multiple doses of racemic epinephrine have not been as established with regards to efficacy and safety as albuterol. Terbutaline is also an effective beta agonist. Although it is not available as a nebulized solution, some experts have nebulized the intravenous form at a standard dose of 5 mg with good results but at a significantly higher cost than albuterol. Although inhalation is the preferred route of administration for beta agonists, parenteral beta agonists may be required for children with severe exacerbations for whom inhaled therapy is ineffective or infeasible. In very severe attacks, inspiratory flow may be too poor to allow for adequate drug delivery to the small airways, and parenteral may be the only route to effectively provide beta agonist therapy. A systematic review by Travers et al recently called into question the efficacy of parenteral beta agonists, but a paucity of pediatric data as well as variability among studies makes this review difficult to interpret for children.

Terbutaline and epinephrine are generally well tolerated and can be administered via the subcutaneous or intravenous routes at 0.01 mg/kg. Major side effects are rare but can be significant with arrhythmias, tachycardia, hypertension, and cardiac ischemia among the most serious. Parenteral beta agonists may be considered for critically ill children or for children who fail to respond to inhaled therapy.

Alongside beta agonists, systemic corticosteroids are a mainstay of therapy in acute asthma. Corticosteroids work by suppressing inflammation at the cellular level and are effective for both chronic and acute inflammation. In addition, corticosteroids and beta agonists have synergistic effects. Corticosteroids can increase the expression of beta agonist receptors and prevent their downregulation when beta agonists are administered.

Inhaled corticosteroids are commonly employed as anti-inflammatory therapy in persistent asthma, but there is inadequate evidence to recommend their use alone in acute asthma or in addition to systemic corticosteroids. Although clinical improvement after the use of systemic corticosteroids is not immediate, their early use has been shown to decrease hospitalization rates in children with acute asthma exacerbations.

Corticosteroids have also been shown to decrease the rate of relapse. Prednisone (1-2 mg/kg/day) is commonly used as oral outpatient therapy and has minimal side-effects in short bursts. Noncompliance with 5 days of therapy is common. Alternatively, 2
Risk Management Pitfalls For Acute Asthma

1. “My patient is wheezing, so he must have asthma.”
   Although asthma is a common cause of wheezing, several other etiologies can result in a very similar picture. Bronchiolitis and airway foreign bodies are common imitators of asthma that may be difficult to distinguish from an asthma exacerbation but require very different therapy.

2. “My patient is not wheezing, so this must not be asthma.”
   Some patients with severe exacerbations will have enough limitation in airflow that they will not wheeze despite severe bronchospasm. Patients with this “silent chest” are at risk for a poor outcome unless treated aggressively for a severe asthma exacerbation. In addition, “cough-variant” asthma may not present with wheezing but with a history of persistent cough, particularly at night.

3. “My patient is dyspneic, so I must get a chest x-ray.”
   For most patients, chest x-rays add little to the clinical assessment of asthma. Abnormal chest x-rays are common in children with acute asthma but rarely result in changes to management. Generally, only if the diagnosis is in question or if there is fever or focal examination findings will a chest x-ray be helpful.

4. “My patient’s blood gas looks OK, so her exacerbation must not be too severe.”
   Since pulse oximetry is now readily available, blood gases generally have little to offer in acute asthma. As there are no laboratory definitions for respiratory distress or failure, patient history and physical are the keys to the diagnosis of severe asthma and the decision to intervene. In addition, many children are able to compensate for severe respiratory distress, often until respiratory failure is imminent, thus reliance on blood gas results may give a false sense of security.

5. “My patient isn’t used to performing peak flows at home, so we’ll just assess him clinically.”
   Not all children are able to participate in measurement of peak flow in the emergency department, but if this measurement can be obtained, it is a valuable assessment tool for the severity of the exacerbation and its response to treatment. Many children age 6 years of age or older are able to perform peak flows, and performing this in the emergency department gives practitioners an opportunity to reinforce and educate regarding the use of peak flow meters for home management.

6. “It’s only a mild exacerbation; I don’t think I need to give corticosteroids.”
   Corticosteroids target the inflammatory component of asthma and are a mainstay of acute asthma therapy. Even for mild exacerbations, corticosteroids have been shown to improve symptoms and decrease the rate of relapse and return visits to the emergency department. Corticosteroids are best given early in an exacerbation.

7. “My patient is on inhaled corticosteroids at home; I’ll just give that to her rather than systemic corticosteroids.”
   Although inhaled corticosteroids are crucial in the daily control of asthma, they offer little to the acute management. Previous guidelines suggested doubling the dose of inhaled corticosteroids during exacerbations, but this has been unsupported in recent literature. For exacerbations, systemic corticosteroids are required to treat inflammation.

8. “I gave inhaled albuterol, but it didn’t help, so it must not be asthma.”
   Patients with severe exacerbations or prolonged symptoms prior to presenting to the emergency department may show poor initial response to albuterol. For these patients, continued aggressive therapy for their asthma is critical.

9. “My patient is agitated on continuous albuterol, so I gave a dose of a benzodiazepine.”
   Although inhaled beta agonists can cause tremors, tachycardia, and jitteriness, agitation in the setting of respiratory distress is potentially a sign of respiratory failure. Careful assessment for other signs or symptoms of respiratory failure is essential, particularly before treating with a drug that could further depress respiratory ability.

10. “I am not a primary care provider, and I don’t feel it’s my role to start daily controller therapy for children with persistent asthma.”
   Numerous studies and clinical guidelines suggest the emergency department is an appropriate and effective setting to initiate treatment with daily controller therapy for patients with persistent asthma. For many patients, the emergency department may be the only point of contact with the health care system, and prescribing daily controller therapy for patients can be crucial in maintaining control of a child’s disease.
doses of daily dexamethasone (0.6 mg/kg/day) has been shown to be as effective as 5 days of prednisone, with the additional benefits of decreased vomiting and increased compliance. Some experts have also used shorter courses of corticosteroids or single-dose dexamethasone given intramuscularly or by mouth with good results and increased compliance. Although offering no benefits over oral administration with regards to onset of action or potency, corticosteroids such as methylprednisolone may also be administered intravenously if oral administration is not tolerated or feasible.

Theophylline or its intravenous form, aminophylline, is another drug long used in asthma therapy. Once commonly used as maintenance therapy for asthma, chronic use of theophylline in children is now rare, and its uses in the emergency department are limited. Aminophylline has not shown any benefit for children with mild or moderate asthma exacerbations, even among those requiring hospitalization. In critically ill children unresponsive to other therapies, aminophylline may improve lung function over several hours to days but has not been shown to acutely reduce symptoms, avoid intubation or intensive care unit admission, or decrease length of stay. In addition, aminophylline may result in undesirable side effects, particularly vomiting, headache, abdominal pain, and palpitations. With its narrow therapeutic range requiring repeated assessment of drug levels and high incidence of toxicity, aminophylline offers no benefits in the acute emergent management of asthma.

For children presenting with severe asthma exacerbation who are not responding to initial therapies, intravenous magnesium sulfate may be a therapeutic option. Used as a smooth muscle relaxant, magnesium is thought to promote bronchodilation. Although a definite therapeutic benefit has yet to be proven, several studies suggest it may decrease admissions and improve lung function for children with severe exacerbations. Magnesium is generally well-tolerated at 25 to 75 mg/kg over 20 minutes and has a good safety profile with minimal side-effects. Rarely, hypotension can result from administration secondary to the smooth muscle relaxation effect. Inhaled and oral magnesium have not yet shown any benefit in acute asthma in children.

Blocking of leukotrienes is a relatively new strategy in the treatment of asthma. As mediators of inflammation, leukotrienes are minimally affected by corticosteroids, and the addition of oral leukotriene receptor antagonists (LTRAs) such as montelukast to daily asthma treatment can improve lung function and reduce symptoms and exacerbations for many children. Although LTRAs have some bronchodilator effects, it is unclear if there are benefits of using LTRAs in the acute setting. There is some evidence that montelukast may improve symptoms in young children with mild exacerbations, but this has not been reproduced in older children with more severe exacerbations. LTRAs are a novel area for research, and more studies in children are needed before they can be recommended in the acute setting.

The most common acid/base disorder among children with status asthmaticus is respiratory alkalosis as carbon dioxide is released by hyperventilation. Occasionally, critically ill children receiving beta agonists for status asthmaticus can develop lactic acidosis. This is due not only to respiratory muscle overuse and decreased peripheral perfusion, but also due to volume depletion from respiratory losses and as a side effect of beta agonists. Beta agonists contribute to lactic acidosis by promoting gluconeogenesis, glycogenolysis, and lipolysis. This lactic acidosis manifests as worsening respiratory distress with compensatory hyperventilation. In this case, ensuring adequate intravascular volume and reassessing beta agonist therapy may be helpful to ameliorate the lactic acidosis and subsequent hyperventilation. Additionally, the increased intrathoracic pressure from air-trapping in severe asthma cases results in decreased right-ventricular filling and reduced preload, requiring volume expansion to help with systemic perfusion. Overhydration should be avoided, as acute asthma can be associated with increased secretion of anti-diuretic hormone.

Ketamine may be another useful adjunct in the care of children with severe, refractory exacerbations. Primarily used as a dissociative amnestic drug for procedural sedation, ketamine promotes bronchodilation and bronchorrhea, which may aid in clearing mucus plugs. At low doses ketamine has not been shown to be effective, but at sedative doses it has been reported in small studies to provide significant improvement in respiratory distress for some individuals with refractory, life-threatening exacerbations. Ketamine must be used with caution since side effects include hypoventilation, hypertension, laryngospasm, and emergence agitation. Ketamine is an excellent choice of sedative for children requiring rapid-sequence intubation for life-threatening asthma.

For the child with refractory status asthmaticus, heliox may be beneficial. Heliox is an inert, low-density gas. Whereas room air is primarily nitrogen and oxygen, heliox provides a mixture of helium and oxygen, which promotes less turbulent airflow through narrowed airways. This may reduce the work of breathing and promote inhaled drug delivery. Although unlikely to be beneficial in patients with mild-to-moderate symptoms, several studies suggest heliox may improve respiratory distress and prevent respiratory failure in select children with severe obstruction, particularly when...
Clinical Pathway For Management Of Acute Asthma

Ascertain a brief history, physical exam, vital signs, and peak flow if able. Assess severity of asthma.

**Mild exacerbation**  
PEF > 70%  
No activity limitations occur.

Provide an inhaled beta agonist and oral corticosteroids.  
(Class I)

Symptoms resolve.  
PEF > 70%

Discharge with an inhaled beta agonist q4h and oral corticosteroids. Consider daily controller therapy.  
(Class I)

**Moderate exacerbation**  
PEF 40% to 70%  
Some dyspnea with activity may occur.

Provide an inhaled beta agonist and oral corticosteroids.  
Consider ipratropium.  
(Class I)

Symptoms persist.  
PEF < 70%

Admit for frequent inhaled beta agonists and corticosteroids.  
(Class I)

No respiratory support needed.

Admit to pediatric critical care unit.

**Severe exacerbation**  
PEF < 40%  
Dyspnea occurs at rest.

Provide an inhaled beta agonist and oral corticosteroids.  
Consider inhaled ipratropium.  
(Class I)

Consider IV magnesium.  
(Class II)

Symptoms persist.  
PEF < 40%

Respiratory support needed.

BiPAP and intubation are recommended.  
(Class III)

The evidence for recommendations is graded using the following scale. For complete definitions, see back page.  
Class I: Definitely recommended. Definitive, excellent evidence provides support.  
Class II: Acceptable and useful. Good evidence provides support.  
Class III: May be acceptable, possibly useful. Fair-to-good evidence provides support.  
Indeterminate: Continuing area of research.

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient’s individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

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used early in the treatment course. In patients requiring significant oxygen supplementation, heliox can be challenging to utilize; oxygen concentrations greater than 30% significantly reduce the efficacy of heliox.

Although respiratory failure is fortunately infrequent in asthma, occasionally children will present with acute severe exacerbations, and respiratory support may be required. Bi-level positive airway pressure (BiPAP) ventilation can offer significant respiratory support to select patients with status asthmaticus and may allow these patients to avoid intubation and intensive care unit admission. For patients with severe distress, BiPAP may facilitate administration of inhaled beta agonists. BiPAP is safe and is generally well tolerated and may improve oxygenation and decrease work of breathing. Clear guidelines for its use are not yet established, but for the child with refractory symptoms, BiPAP may offer an alternative to intubation if used in a timely fashion.

For refractory patients with impending respiratory failure, intubation may be necessary. The decision to intubate a child with status asthmaticus should never be taken lightly and should be done in a patient with waning mental status and progressive bradypnea or bradycardia. Every attempt should be made to maximize beta agonism via both inhaled and intravenous routes in addition to corticosteroid therapy before considering intubation. Other adjunctive therapies previously mentioned should also precede intubation if possible. Patients with life-threatening asthma are often challenging to ventilate, and strategies to promote exhalation are typically helpful. Prolonged expiratory times with small tidal volumes and slow ventilatory rates can help avoid progressive hyperinflation (auto-PEEP). High ventilatory pressure is best avoided as it can result in barotrauma. Oxygenation is a priority as hypercapnia is often well-tolerated. Inhaled general anesthetic agents such as isoflurane may be an option in the intensive care unit to promote bronchodilation. For children refractory to all other therapies, extracorporeal membrane oxygenation (ECMO) may be a last resort.

Controversies/Cutting Edge

The assessment and treatment of acute childhood asthma is an exciting area for research. Capnography has been shown to be feasible in the emergency department, and may offer an additional assessment tool. Cutting edge markers for airway inflammation such as increased exhaled nitric oxide, urinary leukotriene E4, and sputum eosinophils may soon be available as diagnostic and assessment tools, particularly for young children with asthma.

New treatments are also under development, including therapies specifically targeting immunoglobulin E (IgE). Omalizumab, a monoclonal anti-IgE antibody is approved for children over 12 years of age with moderate to severe asthma as part of their maintenance therapy, but it has yet to be studied in acute exacerbations.

Disposition

Determining who is safe to discharge and who requires hospitalization can be challenging in children with asthma exacerbations. Clearly, children with hypoxia or moderate to severe symptoms after treatment should be admitted. Peak flows are a helpful adjunct in children able to perform them. Often, children with a post-treatment peak flow less than 70% of expected will require admission, and peak flows less than 40% may trigger admission to the intensive care unit. Even among children with a good initial response, factors such as the presence of wheezing for 2 or more days prior to presentation or a history of frequent recent acute asthma visits, fever, or severe persistent asthma may place a child at risk for a poor short-term outcome. For those patients stable for discharge, close follow-up with a primary care physician is essential. Interventions shown to increase short-term patient follow-up include free medications, transportation vouchers, assistance in scheduling appointments, and follow-up telephone coaching.

Long-term daily controller therapy is strongly recommended for children with persistent asthma. Inhaled corticosteroids are the most common daily controller therapy and have been shown to improve asthma control with less need for rescue medications, fewer urgent visits, fewer hospitalizations, and fewer asthma deaths. Despite the benefits, many children are not treated. The emergency department may be the only point of contact with the medical system for some children and is an appropriate place to initiate therapy in conjunction with a child’s primary care physician.

Daily controller therapy should be considered for young children with greater than 4 episodes of wheezing in the last year or 2 exacerbations requiring corticosteroids within 12 months. For older children reporting symptoms 2 or more days per week, using rescue medications 2 or more days per week, or experiencing night-time symptoms 2 or more times per month, adding inhaled corticosteroids is indicated. Inhaled corticosteroids such as budesonide or fluticasone are generally preferred, but oral montelukast may be another option. For children already on inhaled corticosteroids but with persistent symptoms, the dose of inhaled corticosteroid may be increased or montelukast may be added to the daily regimen.
Summary

Acute asthma is a diagnosis that requires pediatric emergency care providers to be masters of assessment and management. Timely and aggressive use of inhaled beta agonists and oral or IV corticosteroids are the basis of acute asthma treatment for most children, but several adjunct therapies including terbutaline and epinephrine are available in the emergency department to treat severe exacerbations. Asthma is a common chief complaint in the emergency department and a significant chronic disease for many children. Asthma offers numerous challenges but also offers numerous opportunities for intervention. Pediatric emergency care providers have an opportunity to intercede not only in acute exacerbations but also in the treatment and education for children and families dealing with this chronic disease.

Case Conclusion

You rapidly identify this patient as having a severe asthma exacerbation and needing aggressive management. You start continuous albuterol and ipratropium and administer a dose of corticosteroid. The patient continues to have severe distress and appears anxious. You give subcutaneous epinephrine, place an IV, and administer magnesium and a normal saline bolus. You also ask his respiratory therapist to administer his aerosol medications via BiPAP, which results in improvement in his retractions and anxiety. Within 15 minutes, wheezing is audible in his lung fields. You reassess him frequently, and his respiratory rate decreases over the next hour, after which you transition him to aerosols via a simple mask, which he tolerates well. After 2 hours, he is able to speak in full sentences and perform a peak flow, which is 50% of expected. You are able to transition him from continuous albuterol aerosols to intermittent treatments every 2 hours, but his oxygen saturations remain 92% while on room air. You contact his primary care physician and admit him to the hospital for continued treatment of his acute asthma exacerbation. He remains in the hospital for 2 days, after which he is discharged on an increased dose of fluticasone as a daily controller medication.

References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study, will be included in bold type following the reference, where available. In addition, the most informative references cited in this paper, as determined by the authors, will be noted by an asterisk (*) next to the number of the reference.

1. Avoid diagnostic testing for acute asthma. Unless the diagnosis is in question, diagnostic tests such as chest x-rays or laboratory tests rarely add to the clinical assessment of acute asthma. Measurements of pulmonary function other than peak flows are generally not feasible from the emergency department.

2. Consider administering continuous beta agonist therapy. Setting up a patient with 2 hours of nebulized solution may offer an opportunity for cost-containment in the emergency department as it is less labor-intensive for caregivers. Vigilant assessment is necessary since continuous therapy may result in fewer scheduled opportunities for patient assessment.

3. Prescribe short courses of corticosteroids for acute asthma and inhaled corticosteroids for daily controller therapy. Corticosteroids are critical to the treatment of acute asthma and have been shown to decrease not only the need for admission but also the rate of relapse and return visits to the emergency department. In addition, prescribing inhaled corticosteroids as daily controller therapy for children with persistent asthma may decrease the frequency of exacerbations and the subsequent need for acute visits.

4. Consider using adjunct therapies for refractory acute asthma. Although not routinely recommended, several adjunct therapies exist that may be helpful in children with severe asthma not responding to inhaled beta agonists and corticosteroids. Adjunct therapies such as magnesium, heliox, and BiPAP in the emergency department have all been shown to be safe and well tolerated, and they may allow patients to avoid admission to the intensive care unit.

Cost-Effective Strategies

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**CME Questions**

1. **Risk factors for asthma in children include all of the following EXCEPT:**
   a. Young age (under 4 years of age)
   b. Puerto Rican or non-Hispanic black heritage
   c. Low socio-economic status
   d. Female

2. **Consequences of inadequately controlled asthma include all of the following EXCEPT:**
   a. Irreversible airway thickening and fibrosis
   b. Increased airway hyperresponsiveness
   c. Increased airway mucus secretion
   d. Bronchiectasis

3. **Which historical element is most concerning for a severe exacerbation?**
   a. A patient’s report of the severity of their exacerbation
   b. An increase in baseline use of albuterol from 1 to 3 times per week
   c. A recent diagnosis of asthma
   d. Wheezing for the last hour

4. **What is the most effective objective assessment tool for asthma?**
   a. Asthma score
   b. Peak expiratory flow
   c. Pulse oximetry
   d. Arterial blood gas

5. **Respiratory failure in asthma is best diagnosed by:**
   a. Oxygen saturation less than 90%
   b. Arterial blood gas with pCO₂ > 40 mmHg
   c. Physical examination
   d. Respiratory rate > 50

6. **In which of the following patients would a chest x-ray be indicated?**
   a. A 6-year-old with a history of asthma and a “silent chest”
   b. An 18-month-old with wheezing for the first time
   c. A 12-year-old with wheezing and fever
   d. A 2-year-old with an upper respiratory infection and continued wheezing after albuterol

7. **Which of the following methods of administering albuterol is not indicated for acute asthma?**
   a. Oral
   b. Continuous nebulization
   c. Intermittent nebulization
   d. Intermittent metered-dose inhaler

8. **Inhaled ipratropium would be most beneficial for which of the following patients?**
   a. A 5-year-old being hospitalized for asthma
   b. A 10-year-old with intermittent wheezing with exercise
   c. A 9-year-old with moderate persistent asthma uncontrolled at baseline
   d. A 12-year-old with an acute severe exacerbation

9. **All of the following are acceptable methods of administering corticosteroids for acute asthma exacerbations EXCEPT:**
   a. Oral prednisone
   b. Oral dexamethasone
   c. Inhaled fluticasone
   d. Intravenous methylprednisolone

10. **Which adjunct therapy is most beneficial for acute asthma in the emergency department?**
    a. Magnesium sulfate
    b. Aminophylline
    c. Montelukast
    d. Inhaled budesonide

11. **Heliox may offer a benefit in acute asthma by:**
    a. Decreasing mucus production
    b. Promoting bronchodilation
    c. Minimizing inflammation
    d. Decreasing turbulent airflow
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Class Of Evidence Definitions

Each action in the clinical pathways section of Pediatric Emergency Medicine Practice receives a score based on the following definitions.

Class I
- Always acceptable, safe
- Definitively useful
- Proven in both efficacy and effectiveness

Level of Evidence:
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II
- Safe, acceptable
- Probably useful

Level of Evidence:
- Generally higher levels of evidence
- Non-randomized or retrospective studies: historic, cohort, or case control studies
- Less robust RCTs
- Results consistently positive

Class III
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate
- Continuing area of research
- No recommendations until further research

Level of Evidence:
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling


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