



Inpatient management of an acute asthma exacerbation using clinical care pathways

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Asthma exacerbations remain a leading cause of hospitalization in the pediatric population, and many children who require hospitalization for status asthmaticus are managed using clinical care pathways (CPGs). Clinical care pathways are often created or adopted by healthcare systems in order to establish specific, evidence-based guidelines that standardize and coordinate quality care in both the emergency room and inpatient settings.

This paper reviews the use of these guidelines and the updated evidence-based recommendations regarding best-practice for acute asthma care of hospitalized children, including the 2020 recommendations from the National Asthma Education and Prevention Program Expert Panel (NAEPP).

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Introduction

Asthma exacerbations are among the leading diagnoses for emergency department visits, and currently rank within the top four indications for pediatric hospitalization.^{1,2} Through the use of clinical care pathways (CPGs), many children's hospitals have standardized and streamlined the emergency room and inpatient management of children with acute asthma exacerbations—an effort that has been proven to decrease length of stay, reduce costs, and minimize prolonged use of β -agonists without adversely affecting readmission rates or progression to higher levels of care.³⁻⁶ A clinical care pathway typically details inclusion and exclusion criteria for utilization of the protocol; provides a scoring tool to objectively assess a child's respiratory status and severity of symptoms; outlines the preferred dose, route and frequency for the medications recommended, including a stepwise approach for weaning or advancing therapy; and provides guidelines for considering adjunctive therapy if the child's respiratory status is stagnant or worsening. Further, the treatment protocol for asthma is

often designed to be used by nurses and respiratory therapists (in addition to physicians and advance practicing providers). This model ensures children are weaned from therapy in a timely manner as symptoms improve, thus minimizing the influence a single clinician's availability for frequent re-assessments can have on the trajectory of the child's care.

This paper consolidates and reviews the evidence-based practices consistently recommended in clinical care pathways for asthma across a number of institutions. It focuses specifically on the management of an acute exacerbation in the emergency department and the non-ICU inpatient setting.

Pathway eligibility

The preliminary focus for each clinical care guideline involves determining the patient population that is best suited for management under the standardized approach. While each institution maintains its own inclusion and exclusion criteria, eligibility for using a standardized asthma management pathway consistently includes the following: age greater than or equal to two years, prior diagnosis of asthma or history of two significant wheezing episodes responsive to β_2 -agonists, and clinical evidence of an asthma exacerbation without a coinciding or alternative diagnosis of aspiration pneumonia, bronchiolitis, or croup. Patients with chronic conditions like cystic fibrosis, restrictive lung disease, bronchopulmonary dysplasia, and cardiac disease are often excluded from the pathway. Patients with concerns for—or a previous diagnosis of—an airway disorder (e.g. vocal cord

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paralysis, tracheomalacia, tracheostomy dependence, etc) are often excluded from the pathway as well.⁷⁻¹¹

Asthma severity scoring

After establishing a child's suitability for management under a standardized asthma pathway, the clinician must estimate the degree of airway obstruction, typically through the use of a respiratory severity scoring system. Several asthma severity scales have been established and validated, the Pulmonary Score (PS), Pediatric Asthma Severity Score (PASS), and the Pediatric Respiratory Assessment Measure (PRAM) are examples of common scales. Although a single severity tool has not been universally adopted, an aggregate asthma severity score (or a classification of mild, moderate, or severe¹⁰) is typically based on a number of physical signs including respiratory rate, accessory muscle use, air movement with intensity of wheeze, and oxygen saturation based on pulse oximetry. The Texas Children's Hospital Asthma/Recurrent Wheezing Clinical Guideline also incorporates the child's color and mental status when determining the severity of the acute exacerbation. Incorporating each of these signs into a composite score—a higher score identifies children with more severe asthma symptoms—enables the managing clinician to tailor the treatment approach to the child's specific needs.

Emergency room management

Key priorities when managing asthma, both in the emergency department and on the acute inpatient service, involve reversal of airflow obstruction with short-acting β_2 -agonists (SABA), reduction of airway inflammation while minimizing the risk of relapse through the use of systemic corticosteroids, and correction of hypoxia—if present—with supplemental oxygen.^{12,13} Albuterol continues to be the mainstay short-acting β_2 -agonist in clinical care pathways for asthma, with the dose and frequency determined by the asthma severity score calculated for each child.

A child with a low asthma severity score is typically given 4-8 puffs of albuterol via metered dose inhaler

(MDI) or 2.5-5mg of albuterol via a nebulized treatment⁷ (Table 1), with weight-based dosing ultimately determining the specific dose for each child. For example, Children's Hospital of Philadelphia recommends administering 4 puffs of albuterol for children weighing 5-10 kg, 6 puffs for children weighing 10-20 kg, and 8 puffs for any child greater than 20kg. However, Seattle Children's Hospital, in comparison, gives 8 puffs of albuterol as the standard dose for all children regardless of weight. Of note, when studied in children with non-life-threatening asthma, a metered dose inhaler with a spacer is equally effective as a nebulized treatment.¹⁴ Therefore, it is often utilized as the first line treatment modality. Due to the SARS-CoV-2 global pandemic, the 2020 guidelines from the Global Initiative for Asthma (GINA) recommend avoiding nebulizers because nebulized treatments increase the risk of disseminating the virus to other children as well as healthcare personnel.

Pressurized metered dose inhalers are the preferred treatment modality for an acute

asthma exacerbation and should be delivered through an aerochamber with a mouthpiece or tightly fitting face mask.¹⁵

Treatment for a child scoring in the middle range of the asthma severity measure typically includes 3 doses of albuterol via MDI or nebulizer every 20 minutes, or the child will be given albuterol continuously via a nebulized treatment with the dose ranging from 7.5mg/hr to 20mg/hr.^{8,7,10} The inhaled anticholinergic medication ipratropium bromide is often added to albuterol for a moderate/severe exacerbation. Ipratropium serves as an antimuscarinic agent by blocking the action of acetylcholine, thereby decreasing smooth muscle contractility and increasing bronchodilation.¹⁶ The dose of Ipratropium ranges from 0.5mg to 1.5mg via a nebulized treatment^{7,11} (Table 1).

When children present to the emergency department with a high asthma severity score, the asthma pathway typically recommends the initiation of continuously nebulized albuterol with ipratropium, and recommends administering an infusion of magnesium sulfate intravenously. Intravenous magnesium sulfate helps relieve bronchospasms by inhibiting mast cell degranulation and by acting as a surrogate for calcium

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TABLE 1. Medications used in acute asthma exacerbations.

Medication	Dosage	Note
<i>Inhaled Short Acting β_2-agonists (SABA)</i>		
Continuous Albuterol Nebulizer Solution 0.5% 5 mg/mL	7.5-20 mg/hr continuous nebulization	<ul style="list-style-type: none"> Paradoxical and transient worsening of hypoxia due to increased ventilation-perfusion mismatching and worsening of intrapulmonary shunting can be seen after administration Other side effects include: tachycardia, tremor, headache, agitation, hypokalemia and ventricular irritability (ex. premature ventricular contractions and ventricular tachycardia). Always use a valved holding chamber (aka aerochamber or spacer) when using a MDI
Intermittent Albuterol Nebulizer Solution 2.5mg/3mL or 5 mg/mL	2.5 to 5 mg q20 minutes to q6hrs or as needed (frequency determined by severity of symptoms)	
Albuterol MDI 90 mcg/puff	4-8 puffs q2-4hrs	
Levalbuterol (R-albuterol) Nebulizer Solution 0.63mg/3mL or 1.25mg/3mL	1.25 to 2.5 mg q20 minutes to q6hrs or as needed (frequency determined by severity of symptoms)	
Levalbuterol (R-albuterol) 45 mcg/puff	4-8 puffs q2-4 hours	
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Ipratropium Bromide Nebulizer Solution 500 mcg/2.5 mL Or Ipratropium with Albuterol Nebulizer Solution (Available 3 mL vial containing 0.5 mg ipratropium bromide and 2.5 mg albuterol)	0.5-1.5 mg (500-1500 mcg)	<ul style="list-style-type: none"> May be used up to 3 times in the initial management of severe exacerbations, and as needed thereafter. Transient dilation of the pupil(s) and blurry vision if the nebulized formulation is blown into the eyes for a prolonged period of time
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<i>Systemic corticosteroids</i>		
Note: Early Emergency Department (ED) treatment with corticosteroids, less than one hour after arrival, is associated with decreased admission rates and shorter ED length of stay for children with asthma exacerbation		
Dexamethasone PO (tablet or liquid)	0.6 mg/kg/day PO q24hr x1-2 doses (16 mg max/dose)	Treatment duration typically ranges from for 3-10 days depending on severity
Prednisone PO (tablet or liquid)	2mg/kg/day PO q24hrs or divided BID (60-80 mg daily max dose)	
Methylprednisolone IV	1 mg/kg IV q12hrs - q6hrs (60-80 mg max per day)	
<i>Adjunct Therapy</i>		
Magnesium Sulfate IV	40-50 mg/kg IV over 30 minutes x1 dose (max dose 2g)	<ul style="list-style-type: none"> The primary systemic side effect of magnesium is hypotension. A bolus of isotonic fluids should be given prior to the magnesium infusion
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Epinephrine: (Available 1:1,000 1mg/mL)	IM: 0.01 mg/kg (0.01 mL/kg/dose of 1mg/mL solution) not to exceed 0.5 mg every 20 minutes for 3 doses	

References: [7,8,10,13,16,17 24](#)

to enable smooth muscle relaxation.¹⁷ The primary systemic side effect of magnesium is hypotension, so a bolus of isotonic fluids is recommended prior to the magnesium infusion.^{13,17} In addition, epinephrine, a non-selective β_2 -adrenergic agonist, and terbutaline, a selective β_2 -adrenergic agonist, are often recommended in clinical care pathways for asthma when there is concern for pending respiratory failure. These agents enhance ventilation by dilating the lung segments that are not being adequately ventilated and thus not receiving the albuterol being administered by MDI or nebulizer.¹⁷

Dexamethasone is becoming the favored first-line steroid for mild and moderate exacerbations;

Regardless of the child's initial asthma severity score, in order to mitigate airway inflammation during the acute exacerbation, asthma clinical care pathways recommend administering dexamethasone, prednisone, prednisolone or methylprednisolone, with the suggestion of delivering the corticosteroid orally whenever possible.⁸ Notably, dexamethasone is becoming the favored first-line steroid for mild and moderate exacerbations; several studies have confirmed the equivalent efficacy of a 1–2 day course of dexamethasone compared to a 3-5 day burst of prednisone or

prednisolone, while improving medication adherence given the shorter duration of treatment with dexamethasone.^{18,16,19} Once the initial therapy has been selected and administered in the emergency room, the child is monitored closely and a new asthma severity score is assigned upon reassessment after the first hour of treatment. A new asthma severity score in the mild range results in an additional 1-2 hours of observation, with the recommendation to discharge home if the child sustains the low asthma severity score. If the new asthma severity score falls within the moderate range, albuterol is readministered via a MDI or nebulizer. Similarly, if the asthma severity score is within the severe exacerbation range, the child will remain on continuous albuterol and escalation of care, such as administration of magnesium sulfate or transfer to intensive care, may be indicated.

Another asthma severity score is assigned during the second hour of care, after the second round of treatment is complete. If the asthma severity score continues to be in the moderate to severe range, then the child is admitted to the inpatient service for ongoing therapy. If a child's oxygen saturation on pulse oximetry is consistently below 90% while on room air despite treatment in the emergency department, then admission to an inpatient service is also recommended.

Inpatient management

The standard of care for ongoing management in the inpatient setting continues to involve a phased change approach based on the asthma severity score, similar to the approach in the emergency department.⁷ The child is reassessed and assigned a new score by respiratory therapists or other members of the care team every 1-4 hours while admitted with subsequent adjustments to the frequency of albuterol. If at any point the child is showing evidence of severely worsening respiratory distress or an acute deterioration, then the rapid response team should be alerted. Otherwise, the child's albuterol is gradually weaned to lower and less frequent dosing based on the ongoing reassessments. For example, based on the Seattle Children's Asthma Pathway, a child admitted from the ED on continuous albuterol will have a new asthma severity score assigned every hour. Once the child has maintained an asthma severity score within the low or medium range for one hour, they will be weaned to the administration of 8 puffs of albuterol every two hours with reassessments then occurring

with every administration. Once the child consistently has an asthma severity score in the low range while receiving albuterol every two hours, the child will be transitioned to every four hour treatments and assessments. On the other hand, if the child is noted to have a high asthma severity score while receiving every two hour treatments, per the asthma pathway, they will be moved back to the previous more intense phase of treatment, which in this example involved continuous albuterol and hourly reassessments. It is important to note the omission of assessments and albuterol treatments occurring every three hours: Similar to other institutions, the pathways implemented at Children's Hospital of Philadelphia, Seattle Children's Hospital and Dayton Children's Hospital enable children to transition directly from every two hour dosing to every four hour dosing, bypassing the administration of albuterol every three hours.^{7,10,11}

While weaning or advancing the albuterol dose and frequency, treatment with corticosteroids persists. If dexamethasone was initially used in the ED, one additional dose is recommended 24 hours after the first dose was given.^{8,9} However, for some institutions, the asthma pathway recommends transitioning from dexamethasone to prednisone or prednisolone if (1) the child is admitted to an inpatient service, (2) the child remains on continuous albuterol upon transfer to the inpatient service, or (3) the child does not improve or clinically worsens following a second dose of dexamethasone that is given 24 hours after the initial dose.^{7,9} Furthermore, any child who was receiving an inhaled corticosteroid (ICS) as controller therapy prior to admission should have the ICS resumed during their inpatient stay.¹¹

Discharge

Explicit criteria regarding a child's readiness for discharge home is a vital component of the clinical care pathways for asthma. Prior to discharge from the hospital, the child should have a low asthma severity score for several consecutive assessments and thus should not be requiring albuterol more frequently than every 3-4 hours. Discharge home is often recommended after the first occurrence of every four hour albuterol dosing, or it is recommended once the child has successfully tolerated every four hour dosing a minimum of two times.⁷ In addition, the child must not have a supplemental oxygen requirement, must be adequately hydrated, and must be tolerating enteral

feeds and fluids.^{7,8,10} Continued bronchodilator therapy every four hours for 24-72 hours or until completing oral steroids is often recommended for ongoing management of the acute exacerbation at home.⁹

Instructions that describe the child's outpatient asthma management should be reviewed with the child and caregiver.

It has been shown that many children and caregivers have difficulty recalling the verbal instructions given by their child's physician, so the National Asthma Education and Prevention Program Expert Panel Report 3 recommends that all children who have asthma be provided a written asthma action plan that includes (1) instructions for daily management of the child's asthma, such as taking medications appropriately, and identifying and avoiding exposure to allergens and irritants that can trigger an asthma flare, and (2) guidelines for recognizing and treating worsening asthma symptoms, as well as instructions that outline when, how, and who to contact if symptoms do not improve or worsen.¹² Most asthma management pathways also recommend that the child be discharged home with all of their asthma medications in hand. This has been shown to decrease the risk of returning to the emergency department within the next 30 days.²⁰ Furthermore, the events of the hospitalization should be communicated with the child's primary care clinician and a follow-up primary care appointment should be arranged prior to the child's departure.

It is worth noting that common practice in the inpatient setting, prior to discharge, has been the initiation of a daily low dose inhaled corticosteroid for children with a history of multiple wheezing episodes, especially when additional evidence of atopy or a family history of asthma exists. However, new guidelines from the National Asthma Education and Prevention Program (NAEPP) regarding the daily management of asthma for both children and adults were released in 2020. The NAEPP recommendations

National Asthma Education and Prevention Program Expert Panel Report 3 recommends that all children who have asthma be provided a written asthma action plan

NAEPP recommends children ages 0–4 years with recurrent wheezing secondary to infections, without wheezing episodes in-between, receive only a short (7–10 day) course of a daily inhaled corticosteroid with as-needed inhaled short-acting β_2 -agonist at the onset of a respiratory tract infection,

regarding the use of inhaled corticosteroids are detailed in Table 2. The NAEPP recommends children ages 0–4 years with recurrent wheezing secondary to infections, without wheezing episodes in-between, receive only a short (7–10 day) course of a daily inhaled corticosteroid with as-needed inhaled short-acting β_2 -agonist at the onset of a respiratory tract infection, as compared to the earlier practice of starting the child on a daily inhaled corticosteroid for longer-term use. Further, for individuals ages 4 years and older with mild to moderate persistent asthma who are likely to be adherent to daily ICS treatment, the Expert Panel conditionally recommends against a short-term increase in the ICS dose for increased symptoms or decreased peak flow. Rather, the Expert Panel

recommends ICS-formoterol in a single inhaler used as both the daily controller and rescue therapy compared to either a higher dose ICS as daily controller therapy and SABA for rescue therapy or the same dose of combination inhaled corticosteroid with long-acting β_2 -agonist (ICS-LABA) as daily controller therapy and SABA for quick-relief therapy. In individuals ages 12 years and older with mild persistent asthma, the Expert Panel conditionally recommends either daily low-dose ICS and as-needed SABA for quick-relief therapy or as needed ICS and SABA used concomitantly. For individuals 12 years of age and older with moderate to severe persistent asthma, the Expert Panel conditionally recommends ICS-formoterol in a single inhaler used as both daily controller and reliever therapy compared to higher-dose ICS-LABA as daily controller therapy and SABA for quick-relief therapy.²¹

Finally, antileukotriene agents like montelukast have traditionally been among the first-line controller therapies for asthma.²² However, an FDA boxed warning was released in March of 2020 regarding montelukast and the risk of serious neuropsychiatric events including suicidality in

TABLE 2. 2020 National Asthma Education and Prevention Program (NAEPP) Recommendations Regarding Inhaled Corticosteroids (ICS) in Children With Asthma.²¹

Group	Recommendation
0-4 years, with recurrent episodes of wheezing associated only with respiratory infections	<ul style="list-style-type: none"> Start short course of daily ICS at onset of respiratory illness, in combination with SABA for quick relief as needed.
≥ 4 years with mild/moderate persistent asthma	<ul style="list-style-type: none"> ICS-formoterol in a single inhaler is recommended for both daily controller and quick relief treatment (Preferred to increased dose ICS daily + SABA for quick relief OR ICS-LABA combination daily + SABA for quick relief) Short-term increase in ICS dosing is not recommended
≥ 4 years with mild/moderate persistent asthma and compliant with daily ICS treatment	<p>EITHER</p> <ul style="list-style-type: none"> ICS daily with SABA as needed for quick relief
≥ 12 years with mild persistent asthma	<p>OR</p> <ul style="list-style-type: none"> ICS + SABA as needed
≥ 12 years with moderate/severe persistent asthma	<ul style="list-style-type: none"> ICS-formoterol in a single inhaler is recommended for both daily controller and quick relief treatment
Abbreviations	<p>ICS: inhaled corticosteroid LABA: long-acting β_2-agonist SABA: short-acting β_2-agonist</p>

Recommendations as reported by the National Heart, Lung, and Blood Institute in the National Asthma Education and Prevention Program Coordinating Committee Expert Panel Working Group's 2020 Focused Updates to the Asthma Management Guidelines.²¹

adolescents and adults, as well as nightmares and behavioral problems in children.²³ Before prescribing montelukast, health professionals should consider its risks and benefits, and children and their caregivers should be counselled about the risk of neuropsychiatric events.²³

Summary

Asthma exacerbations are among the leading causes of children's emergency department visits and indications for hospitalization. Bronchodilators and systemic corticosteroids remain the initial therapies used to reverse the airway obstruction, and clinical care pathways provide a consistent approach to management during an acute exacerbation. A coordinated plan of care for post-discharge management of asthma and future exacerbations should be established prior to the child's discharge home, with consideration of the new NAEPP recommendations released in 2020.

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