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Difficulty Breathing In Infants And Young Children: An Update

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CME Objectives

Upon completion of this article, you should be able to:
1. Identify the most common respiratory emergencies that present to the pediatric ED (asthma, bronchiolitis, and croup) and how they present.
2. Identify the inappropriate diagnostic workups performed commonly for these respiratory emergencies.
3. Discuss controversies in the management of asthma, bronchiolitis, and croup.

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Abstract

Pediatric respiratory distress is a common and troubling presenting complaint to the emergency department (ED). Although many respiratory illnesses are due to upper respiratory tract infections, which are self-limited and need only parental reassurance, the emergency clinician must constantly be alert and prepared for the few children with an underlying condition that can progress to respiratory compromise or failure. Emergency clinicians must utilize clues from both the history and physical examination to uncover the cause of the distress and then employ the most up-to-date modalities to prevent the child's deterioration. Although uncommon, respiratory failure can rapidly ensue in some instances and cause cardiopulmonary arrest. Respiratory failure is the most common cause of cardiac arrest in children.[1] The unexpected and rapid respiratory collapse of the pediatric patient can most often be avoided by early recognition of the severity of illness and should prompt initiation of appropriate therapies.

This review discusses the most common pediatric respiratory emergencies and their management. A detailed discussion of the entire spectrum of respiratory illness in children is beyond the scope of this text. Rather, the review presents an updated, systematic approach to management with careful attention to the relevant existing evidence.

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Case Presentation

You've just come in for the early morning shift. You finish taking sign-outs. As you walk toward the coffee machine, the triage nurse runs by you carrying a toddler in her arms who is coughing, crying, and gasping for air. You follow her to the room, squeeze past 2 frightened parents, a crying grandparent, 2 other nurses, and an EMT student trying to get to the child. They are all trying to keep him on the gurney, place monitor leads, place a nasal cannula for oxygen, and start looking for IV sites. In the meantime, the child's distress continues to worsen, and everyone in the room starts looking at you.

Critical Appraisal Of The Literature

Due to the number of conditions that result in respiratory distress, the literature on this topic is quite extensive and diverse. While certain illnesses are well-studied, the literature on other disease states is sparse. For instance, the scope of the literature on foreign body aspiration is limited to case reports and case series. This is due to the fact that there are only a handful of cases each year that present to a single ED, making it difficult to conduct large studies. On the other hand, there are many large randomized trials and systematic reviews on asthma, bronchiolitis, and croup.

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Asthma Literature

The efficacy of steroids in the management of acute asthma has been well-established for years.[2] Multiple studies have shown oral preparations to be cost-effective and therapeutically equivalent to intravenous (IV) preparations for both acute ED and inpatient management.[3-5] Barnett et al performed a prospective randomized controlled trial on 49 severely asthmatic children and found no difference in hospital admission rates between those given IV and oral steroids.[6] Qureshi et al compared oral prednisone and oral dexamethasone in a prospective randomized trial of 533 children and found equal efficacy between the 2 steroids.[7] In children, the limiting factor in the effectiveness of systemic steroid may be palatability.[7,8] Gries et al looked at the use of intramuscular (IM) dexamethasone as a one-time dose for acute asthma. This study concluded that 1 dose IM (1.7 mg/kg) was equivalent to 5 days of oral steroids (2 mg/kg/d) for mild-to-moderate exacerbations.[9] This may be the regimen of choice for those patients who will not tolerate oral medications or in children for whom compliance is a significant concern. Oral, IM, and IV steroids all have well established literature to recommend their use in acute asthma, and the determination of route will depend on the clinical scenario, but in general, the least invasive route is preferred. Newer oral disintegrating tablet preparations may help to combat the palatability and compliance aspect.

There have also been several controlled clinical trials attempting to identify a role for inhaled corticosteroids (ICS) in the ED setting, either as an adjunct to or in lieu of systemic steroids. Although the results have been conflicting, expert opinion and review of the literature supports the continued use of oral steroids over ICS in acute management.[8,10,11] Schuh et al measured hospitalization rates and forced expiratory volume (FEV_1) in 100 patients, comparing ICS and systemic oral steroids, and found that patients receiving oral corticosteroids had better pulmonary function and a reduced admission rate.[12] Devidayal et al, however, found that patients receiving inhaled corticosteroids had improved clinical indices compared to those receiving oral steroids.[13] Despite some evidence to the contrary, systemic steroids should be used for acute exacerbations. Although a final verdict on inhaled steroids in acute asthma is unclear, current literature does not yet support abandoning the standard approach of early use of oral corticosteroids. The National Heart, Lung and Blood Institute's 2007 report on asthma recommended eliminating the previous recommendation of doubling home ICS in an acute exacerbation in favor of starting oral steroids early. It does recommend consideration of initiation of ICS on discharge from the ED, strongly supporting ICS use for preventing exacerbations.[14]

Several studies have shown that metered-dose inhalers (MDIs) are not inferior to the nebulized route.[15] Some studies have also shown fewer side-effects with the MDI.[16,17] A 2004 meta-analysis that included 6 trials with 491 patients < 5 year of age with asthma concluded that a MDI with a holding chamber is more effective then nebulization in decreasing hospitalization and improving clinical scores. It showed that these finding were even more pronounced in moderate to severe exacerbations.[18]

Intramuscular beta-agonists have been shown to be no more effective than the inhaled preparation. Their use has been deemphasized, and their only role may be in patients with severe restriction in air entry.[19,20]

Anticholinergics

The added benefit of nebulized ipratropium in acute asthma has been addressed in several studies.[21,22] A Cochrane Database Review identified 8 high-quality studies and concluded that multiple doses of ipratropium are more effective than a single dose, and this approach avoids hospital admission in 1 in 12 patients.[22] The clinical efficacy of multiple doses of nebulized ipratropium in children with severe asthma exacerbations is well-established and supported by current national guidelines which recommend multiple doses of 0.25 to 0.5 mg by nebulization or 4 to 8 puffs by MDI.[11, 23] ipratropium has not been shown to be effective for children experiencing mild exacerbations. It does not seem to have a benefit for continued use for hospitalized children.[24]

Magnesium Sulfate

Studies of the utility of magnesium sulfate in pediatric acute asthma have shown conflicting results, making it difficult to draw a definitive conclusion. Ciarallo et al showed significant improvement in hospitalization rates (50% versus 0%) in 30 patients receiving 40 mg/kg IV magnesium sulfate.[25] Scarfone et al failed to show a clinically significant difference in Pulmonary Index score, hospitalization rate, or time-to-discharge from the ED. In this study, a single dose of 75 mg/kg magnesium sulfate or placebo was administered to 54 asthmatic children.[26] The use of hospitalization rate and time-to-discharge from the ED as primary end-points in asthma studies are, in many ways, subjective measures plagued by differences in local physician practice. However, when physiological parameters are the main outcome of interest, studies may have more reproducibility and a different conclusion. Rowe et al performed a systematic review of randomized controlled trials evaluating the efficacy of magnesium sulfate in the treatment of asthma.[27] In their review, although the use of magnesium sulfate did not lead to improvement of peak expiratory flow rates (PEFR) when compared to the placebo group, a subgroup analysis of subjects experiencing severe asthma exacerbations revealed statistically significant improvement in PEFR and in absolute FEV1. So, it would appear that based on the available evidence, although magnesium sulfate does not appear to have a role in the management of mild and moderate asthma exacerbations, it likely has a role in the management of severe exacerbations. The adult asthma literature appears to support this concept.[28] Magnesium's effectiveness in the treatment of asthma is supported by studies showing improvement in lung function and symptoms when given by oral and inhaled routes.[29,30] Current national guidelines support its consideration for those with life-threatening exacerbations after standard treatment has occurred.[11]

Theophylline

Although historically important, the use of theophylline in the treatment of asthma has declined as newer therapies with less risk of toxicity have been developed. Studies of the efficacy of IV theophylline have primarily taken place in the pediatric intensive care unit setting.[31] Although the data show favorable clinical outcomes, the lack of data in the ED setting limits our understanding of the role of IV theophylline in the ED. Given the availability of alternative medications with broader therapeutic windows, the role of theophylline will be relegated to history.

Ketamine

Studies evaluating the efficacy of ketamine in acute asthma exacerbations have had mixed results. In a small observational study of 10 patients experiencing severe asthma exacerbations resistant to standard treatment, patients who received 1.0 mg/kg of ketamine as a loading dose followed by 0.75 mg/kg/hour of a continuous infusion showed decreased respiratory rate, increased O_2 saturation, and improved clinical asthma scores.[32] However, the only randomized placebo-controlled double-blind trial failed to demonstrate significant clinical improvement when compared with placebo.[33] This is likely due to the authors' concern about avoiding dysphoric reactions and the use of small doses (0.2 mg/kg loading dose, which they later reduced to 0.1 mg/kg followed by a 0.05 mg/kg continuous infusion). Although the literature consists primarily of very small case series, there is a role for ketamine as part of a rapid sequence intubation (RSI) protocol when respiratory failure is due to asthma. The bronchodilatory effect of ketamine may make it the drug of choice for RSI in status asthmaticus.[34,35]

For more information on ketamine use in the pediatric ED, see the January 2011 *Pediatric Emergency Medicine Practice* article, "Ketamine: Procedural Pediatric Sedation In The Emergency Department."

Bronchiolitis Literature

Bronchiolitis is a common acute viral-induced lower respiratory tract infection that presents as fever, cough, and wheeze in young children. It is the most common cause of pediatric admissions during the winter months and can result in severe respiratory distress, which causes 200 to 500 deaths per year.[36] Multiple controversies exist on the topic of bronchiolitis. A significant barrier to the study of bronchiolitis is the heterogeneity that is inherent to the disease.[37] Bronchiolitis is not only induced by multiple viral pathogens (ie, respiratory syncytial virus [RSV], influenza, parainfluenza) but has no clearly defined age cut off, making it difficult to differentiate from early asthma or reactive airways disease. Establishing a uniform treatment modality for this heterogeneous disease has proven challenging. Epidemiologic studies of children with bronchiolitis are also hampered by the lack of a criterion standard for diagnosis and variability in local viral prevalence.

Beta-agonists

Inhaled bronchodilators such as albuterol and racemic epinephrine have been extensively studied, and the results have been conflicting. Although the data on beta-adrenergic agents have shown mixed results, meta-analyses by Kellner in 1996, Flores in 1997, and Hartling in 2003 and a systematic review by King in 2004 showed some improvement in clinical score but no effect on disease resolution, hospital admission, or length of stay.[38-41] A Cochrane review in 2006 compared non-epinephrine bronchodilators with placebo and in 8 trials including 468 children there was no difference. Overall the analysis showed a modest improvement in clinical score without improvement in oxygenation or hospital admission rate. The authors concluded that the possible minor clinical benefit is likely outweighed by the increase in cost and side-effects.[42] The American Academy of Pediatrics (AAP) clinical practice guideline states "a carefully monitored trial of alpha-adrenergic or beta-adrenergic medication is an option" but "should be continued only if there is a documented positive clinical response to the trial using an objective mean of evaluation." It further defines that the standard of care for bronchiolitis should not include routine use of bronchodilators.[43] On the other hand, Patel showed that oral albuterol has no effect versus placebo in the children with mild to moderate bronchiolitis.[44] Therefore, the use of oral beta-agonist should be discouraged to prevent side-effects without benefit.

Epinephrine

The use of epinephrine to treat bronchiolitis in the ED also remains controversial. Its use is addressed by the same AAP guideline, making a trial an option with monitoring for effect prior to continued use.[43] Menon et al performed a randomized controlled trial of nebulized epinephrine and compared the clinical effects with those of salbutamol (albuterol).[45] These authors reported that the mean oxygen saturation at 60 minutes was higher in the epinephrine group. In addition, 33% of subjects in the epinephrine group, compared with 81% of subjects in the salbutamol group, were admitted to the hospital. Hartling's review also looked at epinephrine specifically and concluded that there was insufficient evidence to support it use for admitted patients.[40] In 2005, Ralston enrolled 65 children and showed no difference between albuterol, epinephrine, or placebo in hospitalization or O_2 requirement.[46] A multi-center study by Wainwright corroborates this finding. It showed that epinephrine did not significantly change length of stay, respiratory effort, or respiratory rate in 194 infants admitted with a diagnosis of bronchiolitis to hospitals in Australia.[47] Whether epinephrine has a role in the ED management of bronchiolitis has yet to be definitively determined in the literature. Current guidelines for its use mimic the recommendation for beta-agonists.[43] Notably, there are no reports of clinically significant adverse events related to the use of epinephrine to treat bronchiolitis. Due to the heterogeneity of the disease, there may be an as-of-yet undetermined subset of children with bronchiolitis who will benefit from bronchodilators.

Steroids

Several randomized placebo-controlled trials have attempted to determine whether steroids are better than placebo in the treatment of bronchiolitis.[48-54] One study was conducted in a randomized double-blind placebo controlled multi-center ED trial by Corneli and the Pediatric Emergency Care Applied Research Network (PECARN). This definitive study showed no significant difference in rate of admission, length of admission, or clinical score.[55] A 2008 systematic review of the literature also supported this study's conclusion.[56] One recent study in 2009 by Plint showed that a combination of dexamethasone and epinephrine for children with bronchiolitis had a significantly reduced rate of admission. The study enrolled 800 infants < 1 year of age and involved multiple arms with dexamethasone and epinephrine versus placebo. Only the epinephrine and dexamethasone arm had decreased relative risk of admission (0.65 [95% CI, 0.45-0.95]) The statistical significance (P value = 0.02) was rendered insignificant after adjusting for multiple comparisons (corrected P value = 0.07), suggesting that an even larger trial with multiple combinations of medicines may be required for a definitive answer.[57] The current 2006 AAP guidelines for bronchiolitis recommend that steroids not be routinely used for bronchiolitis.[43]

Apnea

The disposition of very young infants with bronchiolitis is also controversial and dependent on many factors. Apnea and rapid deterioration are usually the most feared complications. Several studies showed an association with RSV and apnea in children < 2 months of age, which prompted many clinicians to admit all of these patients.[58,59] Wilwerth conducted a retrospective cohort study of 691 children who were < 6 months of age and were admitted for bronchiolitis, to establish low- and high-risk groups for the development of apnea. Low-risk children included term infants > 1 month of age, premature infants > 48 weeks post conception, and those without witnessed apnea. No low-risk child developed apnea as an inpatient, with a 100% negative predictive value.[60] A review of the literature suggests a low overall rate of apnea in those without underlying medical conditions, but the premature child and the child with co-morbidities likely deserves closer observation.[61] The incidence of apnea with RSV may be no different than other viral causes of bronchiolitis, so clinicians should not be falsely reassured by a negative RSV test.[60,62] The increased risk of apnea and deterioration has been most studied for children with clinical bronchiolitis, and caution should be used when extrapolating to those who test positive but have no lower respiratory tract disease.

Other Treatment Modalities

A 2002 study looked at the diluents used with beta-agonists to determine if 3% saline could decrease symptoms in mild-to-moderate bronchiolitis in children. The double-blinded randomized trial showed improved clinical scores after the first day of illness. A potential mechanism is hypertonic saline's ability to improve mucociliary clearance.[63] Three studies have been performed in the ED setting and have not shown positive results in contrast to the other inpatient and observation unit studies.[64-67] A definitive answer will hopefully arise from ongoing larger clinical trials.[68]

Heliox, a helium-oxygen mixture, has the theoretical benefit of improving laminar airflow through the restricted, inflamed airway found in patients with lower airway obstruction. Several studies have had conflicting results with using heliox for the treatment of bronchiolitis. In 1998, Hollman looked at non-intubated pediatric intensive care unit (PICU) patients and found improvement in clinical scores.[69] In 2000 and 2002, 2 studies on intubated PICU patients had conflicting results.[70,71] When using nasal continuous positive airway pressure (CPAP) in an intensive care unit (ICU) for infants < 2 years of age, heliox decreased CO_2 levels while increasing O_2 levels and improving clinical scores.[72] A Cochrane review in 2010 suggests that more evidence is needed before routine use can be recommended and to determine how to best incorporate it into the care of patients with severe bronchiolitis.[73]

Noninvasive respiratory support can be both a bridge to intubation and a definitive treatment option for patients with severe disease. McKiernan studied high-flow nasal cannulae O_2 and found a decreased need for intubation and a shorter PICU stay.[74] Javouhey showed in an unblinded study that using nasal CPAP or bi-level positive airway pressure (BiPAP) decreases the incidence of ventilation-associated pneumonia and can be used as the primary ventilatory support.[75] In a crossover study, nasal CPAP alone showed improvement in respiratory parameters although (as stated above) when combined with heliox, improvement was amplified.[72]

Croup Literature

Steroids

The treatment of laryngotracheobronchitis (croup) with steroids is well-established.[76] The effects of steroids can be seen within 6 hours of administration, even in mild croup, suggesting that early initiation of treatment should be emphasized. Similar to asthma, recent research efforts have compared corticosteroid routes of delivery and have conclusively demonstrated that the route of steroid delivery does not alter therapeutic efficacy. Donaldson et al found no significant difference in the proportion of croup symptoms resolved at 24 hours in 95 patients receiving either oral or intramuscular dexamethasone.[77] This outcome is relatively novel in the literature and may be a less subjective measure than parental report of improvement by phone.[78] Rittichier and Ledwith found similar results in 277 pediatric patients, although they did not blind patients to the treatment they received.[79] A recent multicenter prospective placebo-controlled trial of 720 children with mild croup found that a single dose of oral dexamethasone resulted in decreased repeat visits to the doctor, quicker resolution of croup symptoms, less lost sleep in the children, and less stress on the part of the parents.[80] A systematic literature review confirmed that multiple types and preparations of steroids have significantly beneficial effects on revisit rates, frequency of admission, and length of admission.[81]

Cool Mist

Neto et al performed an analysis on the efficacy of cool mist in the ED treatment of croup. Seventy-one patients with moderate croup were assigned to receive either mist or no mist, and they found no significant difference between the groups with regard to croup score or vital signs.[82] This study was supported by the Cochrane review by Moore that found no significant difference in croup scores in randomized controlled trials.[83]

Heliox

Heliox has also been investigated for upper airway obstruction. In a small study, Weber et al compared heliox therapy with racemic epinephrine in 29 patients with moderate-to-severe croup. They found both treatment modalities to improve clinical croup scores with equal efficacy.[84] But this study was underpowered to detect small differences between groups. Heliox therapy may find a role in the treatment of croup in patients who do not tolerate the tachycardia associated with racemic epinephrine, but the current evidence does not support its routine use.[85,86]

Foreign Body Aspiration Literature

The peak incidence for foreign body aspiration is 1 to 2 years of age when a child's mobility and oral tendencies converge. In younger children, food is the most common foreign body whereas older children tend to aspirate non-food items.[87] Often, the choking event is short lived with apparent resolution and then later re-emergence of symptoms including cough, wheeze, and respiratory distress. Any case with a suspicious story including a history of choking followed by cough, dyspnea, fever, or any abnormal physical or chest radiographic findings requires bronchoscopy as > 40% of children will have a foreign body present. [88]

Anaphylaxis Literature

Anaphylaxis was first described 100 years ago and may pose an immediate threat of upper and lower airway obstruction and resultant respiratory distress in children.[89] In 1998, a joint task force on practice parameters defined anaphylaxis as "an immediate systemic reaction caused by rapid, IgE-mediated immune release of potent mediators from tissue mast cells and peripheral basophils."[90] Major causes include medications, foods (most common cause), insect stings, anesthetics, latex, and exercise; approximately 20% are described as idiopathic. Rapid diagnosis and treatment improves efficacy of treatment[91,92] and decreases the incidence of biphasic reactions.[93] In a retrospective review of 13 severe reactions, those who received epinephrine before or within 5 minutes of the onset of severe symptoms survived while those who did not died.[94]

Intramuscular epinephrine (0.01 mg/kg aqueous epinephrine 1 mg/mL (1:1000) [max dose 0.3 mg]) with repetitive dosing every 5 minutes or more frequently if needed is the treatment of choice for anaphylaxis.[91] Although some studies have suggested the use of inhaled epinephrine, Simons failed to confirm efficacy when plasma epinephrine levels did not increase after inhalation.[95] As there have been no comparative studies, this route is not recommended.[96] Due to the increased frequency of arrhythmias when epinephrine is given IV, this route should only be used in cardiac arrest and profound hypotension that is unresponsive to IM dosing.[97]

Supplemental treatment includes the use of supplemental oxygen, supine positioning,[98] H_1 antihistamines (ie, diphenhydramine 1 mg/kg IM, IV, per os [PO] [max 75 mg]), H_2 antihistamines, corticosteroids, nebulized albuterol, vasopressors, glucagon, and IV fluids. There is evidence that the combination of H_1 and H_2 antihistamines may be synergistic.[99] Many references suggest the use of corticosteroids PO or IV in severe anaphylaxis to modulate late-phase response, but there is no consensus or strong evidence to support this common practice.[91,100] Albuterol can be considered for bronchospasm unresponsive to the epinephrine. Rapid IV volume expansion and traditional and/or alternative vasopressors such as glucagon may be required to counteract profound hypotension from vasodilatation and increased vascular permeability.[97,101] None of these second-line agents should be used in lieu of epinephrine for the treatment of anaphylaxis.

The disposition of patients after true anaphylaxis depends on multiple factors, but a period of observation of at least 4 hours after treatment and symptom resolution is recommended.[101] Admission should be considered in cases with previous severe reactions, asthma (higher mortality),[102,103] or inability to readily return for medical care.

Epidemiology

One study found that 17% of all ED visits for children had a diagnosis of a respiratory disease.[104] It is also the most common reason children under 4 years of age are admitted to the hospital. Asthma, bronchiolitis, croup, and pneumonia account for a large percentage of ED and hospital discharge diagnoses.[105] Respiratory emergencies are also a leading cause of pediatric emergency medical services (EMS) activations. One study found that 38% of pediatric EMS activations were for respiratory emergencies.[106] The true incidence of specific respiratory emergencies is again hindered by the subjective nature of diagnosing respiratory distress.

Despite the advances made in medicine, pediatric asthma continues to grow in prevalence and severity, with almost 650,000 yearly ED visits resulting in more than 150,000 admissions in 2007.[107] It is uncertain why there has been a continued increase in the prevalence of pediatric asthma, although the rate of rise has declined over the last decade. Multiples theories exist, including environmental reasons, immunology, and increased disease recognition. The overall morbidity, mortality, and discrepancies in access to care for pediatric asthma have become a national focus. The National Heart, Lung, and Blood Institute's Asthma Education and Prevention program has published guidelines for the management of acute asthma in the ED as well as multiple recommendations for the use of preventative therapy.[11]

Pathophysiology

There are a large number of illnesses with the final common pathway of respiratory distress, yielding a broad differential diagnosis. **(See Table 1.)** In general, conditions that result in upper or lower airway obstruction, airway inflammation, cardiac compromise, or respiratory muscle weakness can result in respiratory distress. Obstruction can be mechanical in nature (foreign body) or structural (laryngomalacia). Due to the smaller diameter of the pediatric airway, any narrowing due to inflammation, bronchoconstriction, foreign body, or compression has a dramatic effect on airway resistance and results in respiratory distress. This effect is amplified by the child's weaker respiratory muscles and more compliant chest wall. The inflammatory process that precipitates many of the listed diseases is a result of the presence of inflammatory mediators like cytokines, histamines, and bradykinin. Treatment of these inflammatory diseases requires the use of anti-inflammatory medications, but the cause is often multi-factorial. This requires the use of multiple medications including steroids, bronchodilators, antihistamines, antibiotics, and immune modulators.

Systemic illnesses can also frequently have respiratory symptoms in children. In response to a systemic disease and the resultant increased metabolic demand, children develop tachypnea because they have limited pulmonary functional residual capacity. Children compensate by increasing their minute ventilation primarily by breathing faster rather than deeper. In addition, young children have less respiratory reserve and tend to show symptoms of respiratory distress earlier in the course of a disease process.

Anatomic differences in children make them more susceptible to respiratory difficulty than adults. Relative to their size, the tongue is large, and the upper airways are narrow. The diaphragm is flatter, giving less mechanical advantage. The pliable chest wall makes the generation of negative inspiratory pressure more difficult. Grunting is uniquely seen in infants and is thought to represent a form of self-induced auto-PEEP (positive end-expiratory pressure), which allows infants to keep their smaller airways and alveoli open. Respiratory failure may manifest as periods of slowed or erratic breathing and/or apnea. Respiratory rate alone should not be used to determine improvement as a patient with asthma who is tiring can have a declining respiratory rate signaling imminent failure. Perfusion and cyanosis will then rapidly worsen, and complete respiratory arrest will follow. In contrast to adult patients, the cause of cardiac arrest in pediatric patients is often secondary to respiratory arrest.[108] The younger the child, the more precipitous the respiratory failure can be, making early recognition and preparation for airway management essential. Preventing the cardiac component on cardiopulmonary arrest is the difference between a 10% and 75% to 93% survival rate.[109]

Etiology / Differential Diagnosis

Due to the broad nature of this subject, it is helpful to discuss the differential diagnosis by sorting this topic into multiple categories. A logical approach to the differential diagnosis of difficulty breathing in children entails dividing the categories based on mechanical etiology. **(See Table 1.)** In this manner, the etiology of respiratory distress may stem from the upper airways, the lower airways, chest wall, cardiac, central nervous system, gastrointestinal, or metabolic causes.

Upper Airway Etiologies

The anatomy of children makes them more susceptible to airway obstruction. The resistance to airflow is inversely related to the radius of the airway to the fourth power, which is called Pouiseuille's law. Thus, any narrowing at the level of the nose, mouth, larynx, or trachea can cause significant obstruction and distress. Upper airway obstructions produce stridor, in contrast to lower airway disorders, which manifest with wheezing, rales, or rhonchi. Nasal congestion alone in a small infant can result in significant symptoms of distress and parental concern. Oropharyngeal conditions such as congenital abnormalities and peritonsillar or retropharyngeal abscesses are important considerations. Tracheolaryngeal inflammation from disease states such as croup, epiglottitis, angioedema, or foreign body aspirations can become life-threatening.

Lower Airway Etiologies

The lower airway symptoms arise from inflammation, bronchoconstriction, obstruction, mucous plugging, or a combination of these factors. Asthma exacerbations demonstrate all of these factors. Bronchiolitis also is characterized by airway inflammation and mucous plugging. Before assuming that a wheezing patient has asthma or bronchiolitis, it is important to consider other etiologies, such as cardiac disease, metabolic problems, or foreign bodies.

Chest Wall / Pleural Cavity

A complex physiologic process that generates negative thoracic pressure is responsible for inspiration. Any condition that mechanically interferes with this process can ultimately result in respiratory distress. The relatively high compliance of a child's chest wall means that air, blood, effusion, or chyle in the pleural space can significantly interfere with normal respiratory mechanics.[110, 111]

Cardiac

Cardiac etiologies of respiratory distress are often overlooked, since the vast majority of children have a healthy cardiovascular system. Nevertheless, acute cardiac disease can result in respiratory difficulty in children by a variety of mechanisms. Infants with cyanotic congenital heart disease will appear cyanotic secondary to shunting of deoxygenated blood to the systemic circulation. These patients often present in the neonatal period, when the ductus arteriosus closes. Often, their cyanosis will not be accompanied by an increased work of breathing and will not be responsive to supplemental oxygen therapy but will require emergent prostaglandin therapy.

Children with acyanotic congenital heart disease may also present with respiratory distress. These cases usually present later in life as compared with children with cyanotic congenital heart disease. These children will present with tachypnea, feeding intolerance, hepatomegaly, and/or possibly wheezing from congestive heart failure. This wheezing is not usually responsive to bronchodilators. Acquired heart disease such as myocarditis and cardiomyopathy may also present with wheezing and tachypnea. These patients may also demonstrate hepatomegaly, poor perfusion, failure to thrive, and difficulty breathing unresponsive to bronchodilator therapy.

Nervous System

Difficulty breathing may be a symptom of a primary neurological disease. A child with a central nervous system malformation such as Arnold-Chiari mal-

Table 1. Differential Diagnosis Of Difficulty Breathing

Upper Airway	Nose	Congestion Adenoid hypertrophy Choanal atresia	Foreign body Trauma Polyps
	Mouth	Peritonsillar abscess Macroglossia	Retropharyngeal abscess Ludwig's angina
	Larynx	Croup Anaphylaxis Foreign body Laryngomalacia Larygospasm	Epiglottis Subglottic stenosis Trauma Vocal cord paralysis Laryngeal papilloma
	Trachea	Tracheitis Tracheo-esophageal fistula	Foreign body Tracheomalacia
Lower Airway	Mainstem bronchi	Foreign body Hemangioma	Papilloma
	Bronchioles	Asthma	Bronchiolitis
	Alveoli / interstitium	Pneumonia Emphysema	Pulmonary edema Sequestration
Chest Wall/ Pleural Cavity		Pneumothorax Chylothorax Diaphragmatic hernia Neoplasm	Hemothorax Empyema Diaphragmatic paralysis
Cardiac		Congestive heart failure Pulmonary hypertension Arrhythmia	Myocarditis Pulmonary embolus
Neurologic	Brain and brainstem	Central apnea Infection	Prematurity Seizure
	Spinal cord	Spinal muscle atrophy Guillain-Barre syndrome	Transverse myelitis
	Peripheral nerve, neuromuscular junction, and muscles	Myasthenia gravis Diaphragmatic paralysis	Botulism Muscular dystrophy
Other	Gastrointestinal	Gastroesophageal reflux	Abdominal distention
	Metabolic	Acidosis Dehydration	Sepsis Toxicologic syndrome

formation may present with central apnea. Patients with spinal cord disease such as spinal muscle atrophy may develop progressive respiratory insufficiency or frequent lower respiratory tract infections from the inability to mobilize secretions. Peripheral neuropathies affecting the neuromuscular junction or muscles of respiration, such as myasthenia gravis, botulism, or muscular dystrophy, can also result in difficulty breathing. One must be careful to differentiate the normal periodic breathing of newborns from the more concerning true central or peripheral apnea. Apnea is defined as a period lasting > 20 seconds, and one should be especially vigilant in premature infants that have not yet or have just recently reached term for apnea of prematurity.[112]

Gastrointestinal

Due to poor lower esophageal sphincter tone and the frequency of being in the supine position, infants are predisposed to gastroesophageal reflux. This can often cause bronchoconstriction that can be mistaken for reactive airways disease. Significant abdominal distension can also cause difficulty breathing in children due to impaired diaphragmatic movement and decreased pulmonary function due to compression. Diaphramatic hernias result in abdominal contents entering the chest cavity, causing significantly respiratory compromise at birth.

Metabolic

Occasionally, respiratory distress can be a symptom of another systemic disorder. Metabolic acidosis, sepsis, and dehydration will result in increased work of breathing as compensation for the acidosis. Many toxicological syndromes that result in metabolic acidosis will also cause respiratory distress. It is prudent to keep this fact in mind, especially when patients are not responding appropriately to the therapeutic interventions.

Prehospital Care

Respiratory emergencies comprise a significant portion of pediatric EMS calls. As mentioned previously, some studies report that up to 38% of pediatric advanced life support (ALS) transports are for respiratory emergencies.[106] Despite this fact, there are only a handful of studies evaluating the prehospital management of respiratory emergencies. A large study assessing the accuracy of field assessment of pediatric patients by EMS found very favorable results.[113] Those results showed an overall accuracy rate of 81.5% for EMS field diagnosis. Furthermore, the study showed that emergency medical technicians were very successful in assessing children with wheezing, which supports enhancing their breadth of practice in this area.

There is a great deal of variability in the scope of practice of paramedics in pediatric respiratory emergencies. Regional protocols usually dictate the treatment of children with difficulty breathing by EMS personnel. One practice that has recently come into focus is the issue of pediatric intubations. In a large study of prehospital pediatric intubation that reviewed 830 consecutive patients assigned to either bag-valve-mask (BVM) or endotracheal intubation (ETI), there was no significant difference in survival to hospital discharge or neurological status at hospital discharge.[114] The high complication rate, high tube dislodgement rate and increased scene time associated with prehospital intubation associated with no difference in outcome has led to recommendations of altering the standard approach of performing pediatric endotracheal intubation in the field.[115] This finding has been corroborated by other studies and has led to the increased recognition of the efficacy of BVM ventilation in the field.[116] The 2005 pediatric advanced life support (PALS) guidelines emphasize the benefits of BVM and deemphasize advanced airway management.[117] Regional variability in experience by EMS (specifically, urban or rural) makes standardization of EMS practice difficult. For more information on PALS, see the November 2009 *Pediatric Emergency Medicine Practice* article, "Push Hard And Push Fast: The Who, How, And Why Of Pediatric Advanced Life Support (PALS)."

Recent studies support the utility of providing asthma treatment prior to arrival to the ED. Regional medical protocols continue to dictate their use, but model protocols were developed by the Center for Disease Control and Prevention in 2004.[118] Previous studies have already documented high EMS success rates for accurately assessing wheezing in children. Richmond et al showed that out-of-hospital basic life support providers can safely administer albuterol for asthmatics aged 1 to 65 years. This is becoming, or has become, the standard of care in many regions.[119]

Emergency Department Evaluation

Management of the airway and breathing is at the top of the ABCs of assessment of any acutely ill or injured child. Therefore, the evaluation of a child experiencing difficulty breathing must proceed promptly and efficiently. When a child presents in significant respiratory distress, the taking of the history, the performance of the physical, and the provision of diagnostic and therapeutic modalities occur almost simultaneously. A focused history and physical examination is critical to rapidly discovering the diagnosis.

History

When a child first presents in respiratory distress, it may be difficult to obtain a detailed history due to the caretaker's anxiety and the limited ability of the child to communicate. Key points to elicit from the patient's history include:

Timing
The rapidity of the onset of symptoms and its progression can give clues to the diagnosis. An abrupt onset of difficulty breathing may suggest a foreign body, anaphylaxis, pneumothorax, or trauma. Mild symptoms followed by an acute decompensation may be noted in bacterial tracheitis, epiglottitis, or myocarditis. Asthma and bronchiolitis often progress for several hours to days prior to presentation. Prolonged or recurrent symptoms may occur with congenital anomalies or a non-obstructive foreign body.

Preceding Symptoms
The presence of preceding upper respiratory symptoms, followed by difficulty breathing, is often present in the history of patients with pneumonia, bacterial tracheitis, croup, asthma, or myocarditis.

Type Of Cough
Certain respiratory conditions have characteristic coughs. If the child is not coughing in your presence, it is often helpful to ask the parent or caretaker to imitate the child's cough. Infants perinatally infected with chlamydia may have a repetitive staccato cough often following a case of conjunctivitis. Incompletely immunized infants or adolescents with waning immunity with paroxysmal cough may have pertussis. The incidence of pertussis has been on the rise since the 1990s, with regional epidemics reported throughout the country. The patients at highest risk of death are those < 6 month of age. Children < 3 months of age lack the ability to generate sufficient negative pressure to "whoop," though most will have a paroxysmal cough. Occasionally, neonates with pertussis can present strictly with apnea or an apparent life-threatening event. A barky "seal-like" cough that gets worse at night is typical of croup and can often be appreciated from across the ED.[120]

Vomiting
Vomiting often occurs in children experiencing difficulty breathing. Post-tussive emesis is common due to the increasing intra-abdominal pressure generated by the cough.

Past Medical History
For the child experiencing acute difficulty breathing, a focused past medical history provides context and may be helpful in identifying children at risk of acute decompensation. A history of allergic reaction is critical to prompt recognition and treatment of food-induced anaphylaxis. But past medical history can also be misleading. For example, many are familiar with the adage: Be wary of asthmatics that have previously been intubated or required ICU admission. However, we were unable to find literature to support this tenet. In fact, a study by Belessis that evaluated risk factors for ICU admission in children with asthma found that significant risk factors included 3 or more presentations to the ED in the past 12 months, an elevated IgE level, oxygen saturation on presentation of < 91%, and longer asthma duration but did not find previous intubation or PICU admission to be predictive.[121]

Former premature infants are at risk for having chronic lung disease, leaving them with less reserve and a decreased ability to compensate in the setting of respiratory illnesses. They also have a higher likelihood of having subglottic stenosis possibly due to direct laryngeal and tracheal trauma. This narrowing makes them more susceptible to upper airway obstruction and possibly a more difficult intubation.[122]

A history of congenital heart disease might suggest the possibility of congestive heart failure instead of a primary pulmonary etiology.

Family History
A family history of asthma, allergies, or atopic disease can guide therapy in patients with wheezing. For example, in infants who are wheezing for the first time, the likelihood of recurrent wheezing or a future diagnosis of asthma is increased in patients with a personal or family history of atopy, asthma, or eczema.[123] This subset of patients which may be more likely to be having the first episode of recurrent wheezing may benefit from corticosteroid therapy,[124] in contrast to those children presenting with viral-induced wheezing who had no benefit from oral steroids in a large placebo-controlled trial.[125]

Physical Examination

General Appearance And The Work Of Breathing
The most important examination often occurs from the doorway of examination room. The general appearance of the child, particularly the mental status and level of distress, should be determined before interaction with the child occurs. More specifically, the aspects of the work of breathing that the emergency clinician should assess are:

How fast?
The first component in the assessment of work of breathing is respiratory rate. This can be promptly assessed at a glance. Tachypnea occurs in a multitude of respiratory disorders. However, respiratory rate cannot be viewed as just a number; it must be taken in the context of the clinical scenario. A screaming toddler breathing at a rate of 60 breaths per minute may not be abnormal. In addition, fever is associated with an increase in respiratory rate of about 2 to 4 breaths per minute for each rise in degree Celsius.[126, 127]

How hard?
The second component in the evaluation is the effort the child is making to breathe. Nasal flaring, body posture (ie tripoding or sniffing position), tracheal

tugging, inability to speak, and chest wall retractions are signs of increased work of breathing. Poor respiratory effort may be a sign of impending respiratory failure due to fatigue. Confusion and alteration in mental status can also be a sign of hypoxia or impending failure.[126]

How loud?

A great amount of information can be obtained from assessing the sound of respirations. In many cases, this can be done without the aid of a stethoscope. For instance, stridorous respirations accompany upper airway obstruction. Clearing the nose with suctioning or repositioning of the patient's head may assist in differentiating true wheezing or lower respiratory sounds from transmitted upper airway noises. Knowing that the absence of wheezing may just mean poor air entry is an important consideration so as not to underestimate disease severity. A muffled or "hot potato" voice can suggest an upper airway obstruction such as epiglottitis, a retropharyngeal abscess, or a peritonsillar abscess, although the latter is typically seen in older children and adolescents.

Vital Signs

Tachypnea is perhaps the earliest vital sign to become abnormal in respiratory distress. Due to the increased metabolic demand, children in respiratory distress are often tachycardic as well. If a fever is present due to an infectious etiology, it will also contribute to the existing tachycardia and tachypnea. Pulse oximetry is an indispensable fifth vital sign.

Head Examination

Examination of the nose and the nasal mucosa can reveal nasal congestion and rhinorrhea, as well as the unsuspected presence of a nasal foreign body. Nasal flaring is an indicator of an increased effort to breathe. A careful oropharyngeal examination should be done to assess for viral exanthems, parapharyngeal or tonsillar swelling, erythema, or exudates. Trismus may suggest a peritonsillar abscess while drooling may suggest a retropharyngeal collection. Angioedema can be isolated such as to the uvula as in Quinckie's disease or recurrent and diffuse as seen in hereditary angioedema due to C1 esterase deficiency which can be life-threatening.[128,129]

Neck Examination

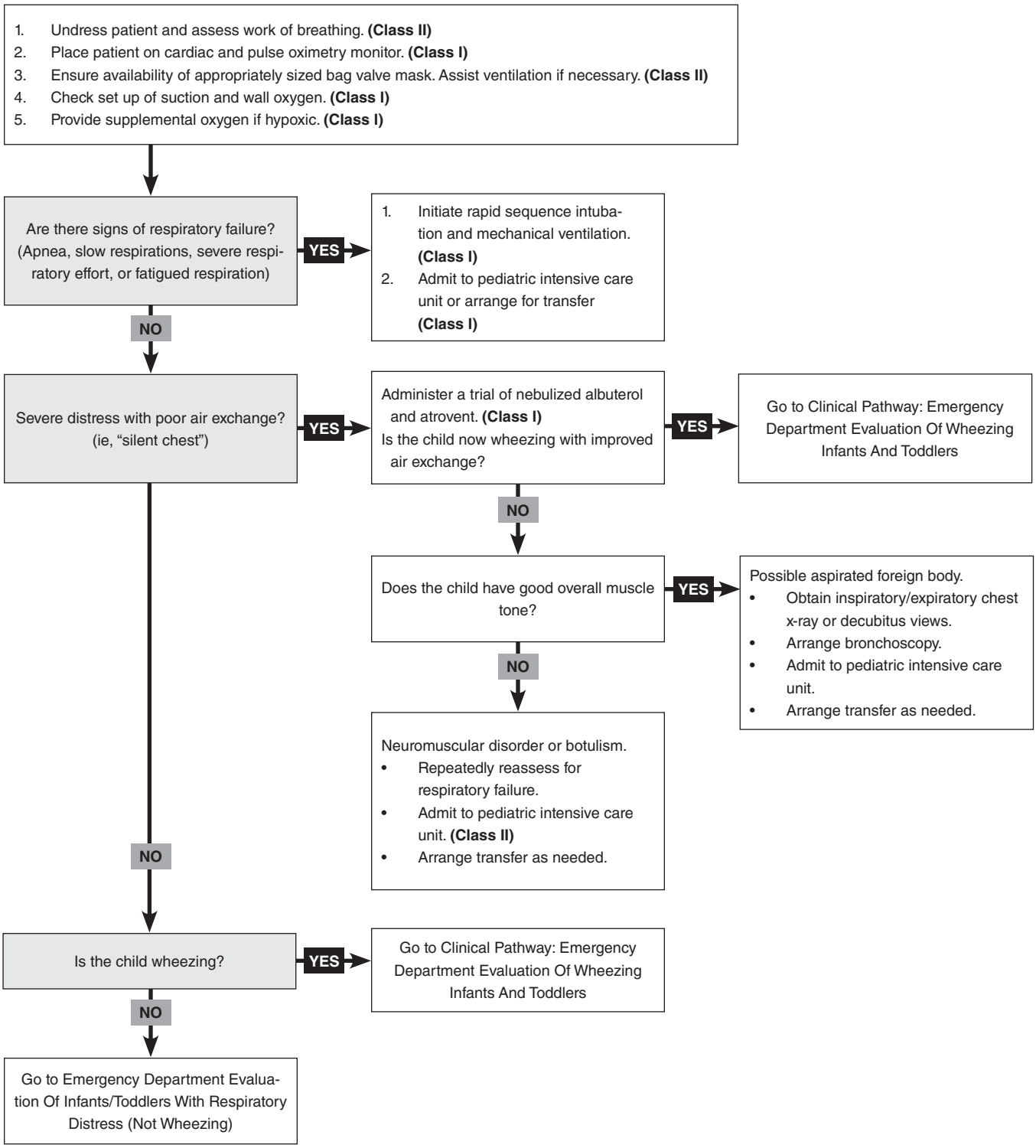
The neck examination frequently may reveal cervical lymphadenopathy due to infectious etiologies. Auscultation of the neck may reveal stridor in the presence of upper airway obstruction. Tracheal shift would be a sign of a tension pneumothorax. Crepitus palpated over the neck can be a sign of pneumomediastinum.

Chest Examination

Differentiating mild abdominal breathing seen in infants from the more severe sternal and intercostal retractions seen in those with significant respiratory distress is an important skill. Auscultation of lung sounds for wheezing and abnormal breath sounds will guide the diagnosis and management. Wheezing is a sign of intrathoracic obstruction versus stridor, which is a sign of extrathoracic airway obstruction. Grunting is a method of maintaining PEEP by expiring against a partially closed glottis. Crackles or rales represent the opening of previous closed air spaces usually during inspiration and are often a sign of an infectious process or pulmonary edema. One must appreciate that a child with both inspiratory and expiratory wheezing has more severe lower airway obstruction. Lack of wheezing can be due to poor air entry, which is an ominous sign in a child with asthma. Auscultation of heart sounds for the murmurs and extra heart sounds may hint at possible cardiac origin of difficulty breathing.

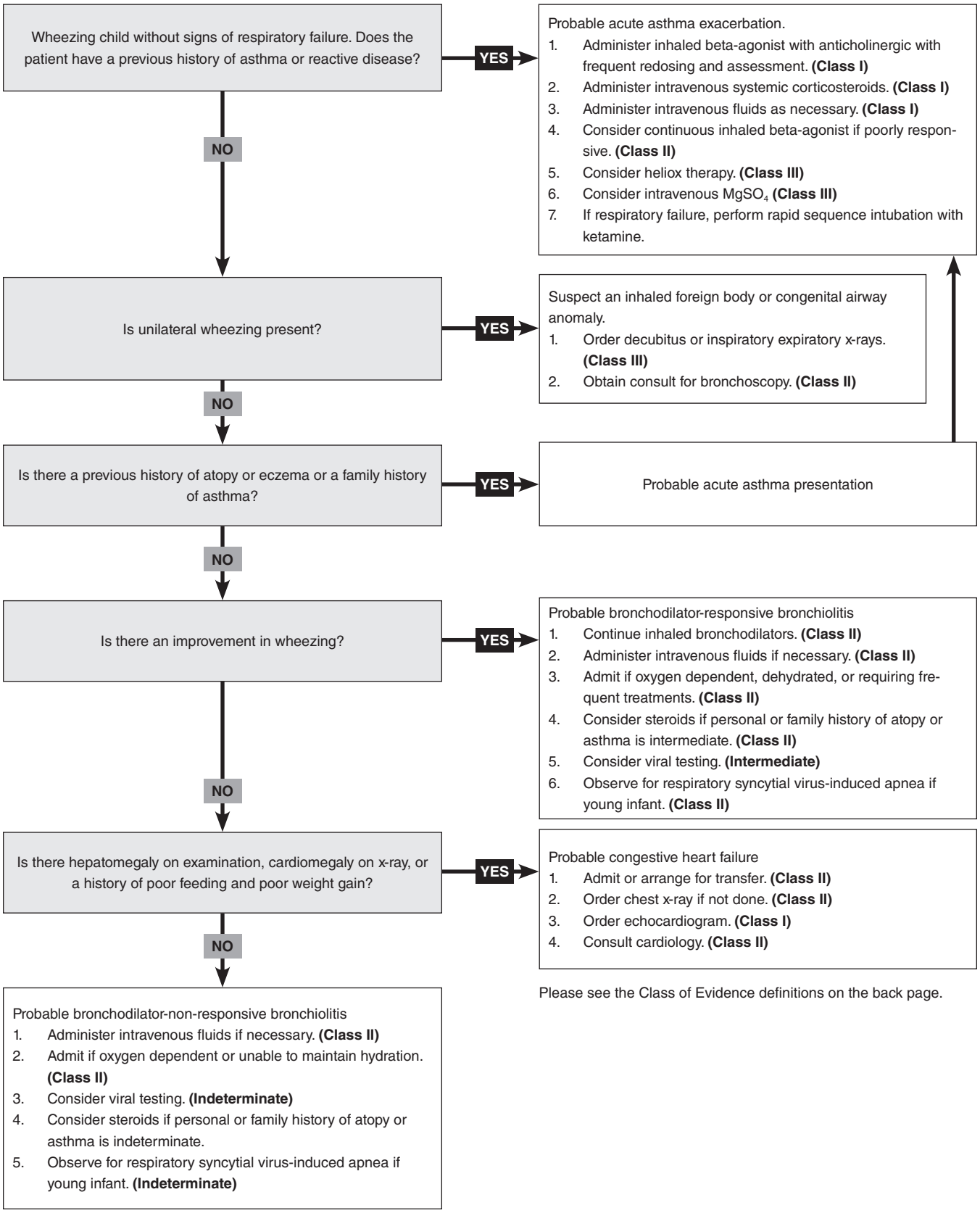
Focal findings such as diminished breath sounds, crackles, or wheezing can represent a focal infectious process such as pneumonia. Treating these patients with antibiotics based on clinical examination has been recommended by the World Health Organization (WHO), especially in resource poor countries.[130] In one study of 570 children, fever associated with decreased breath sounds, tachypnea, and crackles had a 98% sensitivity but only a 7.6% specificity.[131] Another large study showed that clinical lung examination findings poorly correlated with radiographic pneumonia.[132] Rothrock evaluated published Canadian guidelines for predicting clinical pneumonia which suggested that lack of respiratory distress, tachypnea, crackles, and decreased breath sounds excluded pneumonia. This validation study found the guideline to have poor sensitivity and specificity.[133] Clinicians also commonly tout respiratory rate as the best indicator of pneumonia in a febrile child, but this has been challenged by a recent study.[134] Even a study at a tertiary-care pediatric hospital that reported good correlation between physician overall clinical assessment with radiographic pneumonia showed that less than 20% who had the x-ray obtained for "ausculatory findings" had pneumonia. This same study showed that "ausculatory findings" were localized to the correct side of the chest only 25% of the time.[135] Although individual physical examination findings do not correlate well with radiographic pneumonia, the examination is important for generating the physician's overall impression of the likelihood of pneumonia. No clinical guideline has yet been developed that obviates the need for chest x-ray in patients suspected of pneumonia.

Clinical Pathway: Emergency Department Approach To Infant/Child Difficulty Breathing



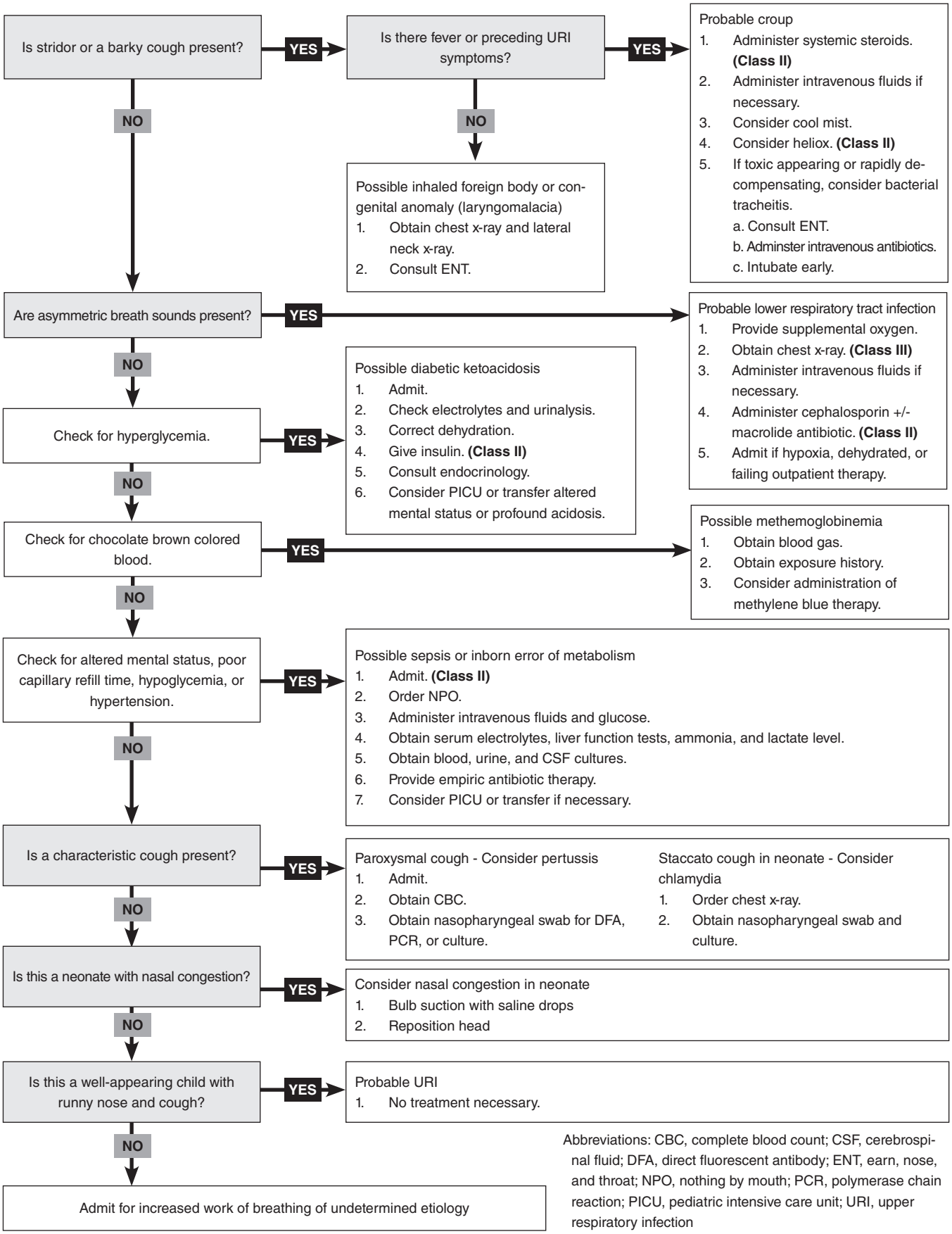
Please see the Class of Evidence definitions on the back page.

Clinical Pathway: Emergency Department Evaluation Of Wheezing Infants And Toddlers



Please see the Class of Evidence definitions on the back page.

Clinical Pathway: Emergency Department Evaluation Of Infants/Toddlers With Respiratory Distress (Not Wheezing)



Abbreviations: CBC, complete blood count; CSF, cerebrospinal fluid; DFA, direct fluorescent antibody; ENT, earn, nose, and throat; NPO, nothing by mouth; PCR, polymerase chain reaction; PICU, pediatric intensive care unit; URI, upper respiratory infection

Abdominal Examination

Abdominal distention is a potential cause of respiratory distress. Due to their pliable chest walls and weak respiratory muscles, children may develop respiratory difficulty due to their inability to counteract the pressures required to breathe against a distended abdomen.[136] Additionally, a careful examination for hepatomegaly will alert the physician to the possibility of a cardiac etiology of the respiratory distress.

Skin Examination

Examine the skin for the presence of cyanosis and rash. Cyanosis is best seen periorally or intraorally. Young infants will occasionally have peripheral cyanosis (acrocyanosis) in cool ambient temperatures, which is not a manifestation of hypoxia. The presence of urticaria in combination with acute respiratory distress suggests anaphylaxis requiring immediate treatment. Facial hemangiomas in the "beard" distribution have been associated symptomatic airway hemangiomas, which should raise the providers concern for airway compromise.[137]

Neurological Examination

A thorough neurological examination is helpful in evaluating the possibility of neurological syndromes that effect respiration. A floppy baby, decreased muscle tone, and generalized weakness can be seen in conditions such Guillain-Barre syndrome, myasthenia gravis, metabolic/mitochondrial disorders, and infant botulism.

Diagnostic Studies

Radiology

Chest x-rays are frequently obtained in the evaluation of respiratory distress. An efficient and cost-effective approach would be to forego chest x-rays when a clinical diagnosis is certain and to obtain them only if a complication is suspected or if the etiology of the respiratory illness is uncertain. For instance, the diagnosis of asthma, bronchiolitis, or croup is often clinical. It therefore seems sensible to obtain x-rays only if there is suspicion of concomitant pneumonia or a complication of asthma such as pneumothorax. In addition, if the etiology of wheezing is uncertain, a chest x-ray may reveal cardiomegaly or an unsuspected radio-opaque foreign body.

A chest x-ray is part of the evaluation of a suspected foreign body aspiration. A high degree of suspicion must always be maintained for foreign body aspiration when a story of choking is obtained. Findings suspicious for a foreign body include a radio-opaque density (present in 6%-15% of cases)[88,138] or unilateral hyperinflation. This hyperinflation may be better demonstrated with inspiratory/expiratory view comparisons in the older child and bilateral decubitus films in the younger uncooperative child, which may demonstrate air-trapping. However, a normal chest x-ray does not rule-out the presence of a foreign body.

Although tradition has been to obtain a chest x-ray in all children wheezing for the first time, a recent study looking at physician practice suggests that films are not routinely obtained in all cases. Findings that were most likely to be associated with positive chest x-ray included fever, absence of family history of asthma, and localized wheezing or rales by auscultation.[139] This finding was confirmed by Schuh et al in 2007, who showed no need for routine chest x-ray in children with a first episode of wheezing with signs and symptoms of bronchiolitis.[140] In 2009, the same group of researchers, lead by Yong, showed the cost-effectiveness of not obtaining x-rays in these patients.[141] Using a chest x-ray in these patients to assess for cardiac disease is low yield, 1 study showed 1 in 140 had a cardiac abnormality which had been suspected prior to the chest x-ray.[142] Similarly, chest x-rays obtained for first-time wheezing had a "definite pneumonia" in only 1.6% of cases.[135]

Neck X-Rays

The utility of neck x-rays in evaluating respiratory distress in children has changed with the routine vaccination of children against *Haemophilus influenzae* type B. The incidence of pediatric epiglottitis has become negligible and subsequently so has the classic radiographic finding of a thickened epiglottis on the lateral neck x-ray. In a similar fashion, despite the traditional description of the steeple sign described in the radiographic literature for croup, children with croup rarely require radiography for diagnosis. Lateral neck films do have utility as a screening tool in the evaluation of retropharyngeal abscess. Although proper positioning is often difficult, plain films can reveal a widening of the retropharyngeal space or less commonly gas pockets or air-fluid levels. A computed tomography (CT) scan provides more detailed information but also has a 10% to 25% false positive rate for indentifying a drainable abscess and a wide variation in reported specificity and sensitivity.[143,144] Computed tomography scans require significant radiation and many retropharyngeal infections (abscesses and phlegmons) can be treated non-surgically with empiric antibiotics unless airway compromise exists.[145-148]

Blood Gases

The utility of obtaining a blood gas in the initial evaluation of a child with respiratory distress is limited. The widespread availability of pulse oximetry in addition to clinical findings is frequently all that are needed to guide clinical decision-making. However, if a metabolic disorder is suspected as the

etiology of the respiratory distress, a pH can be helpful. Arterial sampling for blood gas is not necessary in most situations to obtain the required information. Yildizdas et al investigated the correlation of pH, PO_2, PCO_2, BE, and HCO_3 between an arterial, venous, and capillary blood gas. They found that capillary and venous blood gas analysis yields similar results to arterial sampling for pH, $pC0_2$, BE, and HCO_3 but not for PaO_2.[149] This result is confirmed by several adult studies.[150-152] Venous or capillary blood gas sampling with pulse oximetry is adequate information in the ED evaluation for most situations and is less invasive and more easily obtained.

Capnometry

The use of noninvasive capnometry has been studied in multiple conditions such as in post-op monitoring, procedural sedation, and evaluating sleep apnea. Capnography is a noninvasive measure of ventilation that otherwise would require a blood draw to determine. Recent studies have looked at the utility of capnometry and end-tidal CO_2 ($ETCO_2$) monitoring in the ED evaluation of children with respiratory distress and after intubation. One study found that oral/nasal $ETCO_2$ correlated well with capillary PCO_2.[153] This suggests that continuous monitoring of capnometric CO_2 may be a method to define clinical improvement or impending respiratory failure. A more recent study showed good correlation between $ETCO_2$ and arterial blood gases in adults with acute asthma.[154] Following the trend of the level may provide more utility then obtaining a one-time value.[155] Another study found that capnography can be used to help identify patients with airway obstruction.[156] One study found that capnography was better able to identify cases of apnea > 20 seconds during anesthesia.[157] This study was supported by others, which showed that one can identify deterioration in ventilation sooner with capnography then with pulse oximetry.[158-160] The 2002 practice guidelines by the American Society of Anesthesiologists recommended use of $ETCO_2$ for all deep sedations and when ever direct visualization of the patient is hindered.[161] End-tital CO_2 may also have a role in the acute management of asthma as an effort-independent measure of severity. A 2008 study showed that lower $ETCO_2$ values on arrival and after treatment could predict severity and admissions for moderate asthma exacerbations.[162] This relatively new technology has found a place in the monitoring of children with respiratory distress and those at risk of respiratory compromise.

Pulse Oximetry

Pulse oximetry is noninvasive, conceptually simple, and so commonly used that it has now been considered the fifth pediatric vital sign.[163] When used as a momentary measure of oxygenation, pulse oximetry is an indispensable tool in the ED. There are, however, several limitations and problems with how pulse oximetry is sometimes used. First, there does not appear to be an agreed-upon value at which children should be considered hypoxic. Brown and Dannenberg surveyed 182 general and pediatric emergency physicians and found that physicians had a range of pulse oximetry values at which they reported being comfortable discharging well-appearing children with pneumonia or bronchiolitis from the ED.[164] In this survey, most physicians reported discharge threshold values between 90% and 96%. It has not been shown to be useful as a test to exclude pneumonia or predict return visits for children with bronchiolitis.[165-167]

Respiratory Syncytial Virus Testing

The availability of rapid ED testing for RSV infection has become more common. However, the benefits of identifying the etiologic agent of bronchiolitis in the ED have not been proven. As it is unclear whether viral testing changes provider practice, testing should not be obtained unless the result will impact care.[168] Viral testing is useful for cohorting purposes on inpatient services when beds are limited.

Recent data suggest that infants less than 90 days of age with fever and documented RSV infection have low risk for bacteremia and meningitis.[169-172] Unfortunately, the rate of urinary tract infection in children who test positive for viral infections is still high enough to consider testing.[171] Although further work needs to be done, it is conceivable that in the future, viral testing such as testing for RSV and other viral entities may obviate the need for complete septic work-ups in some infants. Many studies have shown that the advent of rapid testing for viral illness has decreased the rate of other diagnostic testing and shortened the length of stay for febrile children.[168]

Treatment

The management of a child with significant respiratory distress can be very anxiety provoking for both emergency clinicians and staff. Often overlooked are simple measures such as allowing children to maintain their position of comfort. Upper airway obstruction is often exacerbated by the supine position. Rough handling by staff, pulling children from their parent's arms, rectal temperatures, and throat examinations can exacerbate distress. Children with croup and epiglottitis prefer the sitting position. A calm, minimally stimulating environment can often be an important intervention in and of itself. Further management is discussed in the next section and in the clinical pathways.

Airway Management

Oxygen

Providing supplemental oxygen is the most fundamental means of treating respiratory distress and is the first line of therapy. It is important to remember that blow-by and nasal cannula oxygen minimally raise the percent of provided oxygen. Oxygen by mask, though sometimes upsetting to the child, is the only reliable way of significantly increasing the fraction of inspired oxygen.

Bag-Valve-Mask / Assisted Ventilation

Bag-valve-mask is the essential skill in PALS. The new PALS curriculum stresses that it should not be thought of as a temporizing measure prior to establishing a definitive airway but rather as a life-saving treatment.[117] It is important that the mask is of an appropriate size and makes an airtight seal with the patient's face. Proper technique and familiarity with the procedure is of utmost importance and, in many ways, much more important than the ability to intubate.

Endotracheal Intubation

The decision to intubate a child with respiratory distress and impending respiratory failure is multifactorial. In general, a child who is unable to maintain adequate oxygenation and ventilation despite medical interventions may need to be intubated. For the experienced emergency practitioner, the decision is intuitive and is not based upon any set criteria, including blood gas results. Rapid sequence intubation is utilized for all ED patients, as they are all presumed to have full stomachs. Rapid sequence intubation reduces complications associated with intubation and facilitates a successful outcome. A full discussion of rapid sequence intubation is beyond the scope of this article. An outline of this procedure can be found in **Table 2**.[173]

Table 2. Rapid Sequence Intubation

1. Place appropriate monitors (cardiorespiratory, blood pressure, pulse oximeter)
2. Prepare medications and appropriate equipment
3. Preoxygenate with 100% oxygen
4. Premedicate with adjunctive agents if necessary
    a. Atropine (patients less than 6 year old)
    b. Lidocaine (head-injured patients)
5. Administer appropriate sedative agent
6. Apply cricoid pressure (Sellick maneuver)
7. Administer neuromuscular blocking agent
8. Confirm endotracheal tube placement
    a. Pulse oximetry
    b. Carbon dioxide detector
    c. Chest x-ray

Alternative Airways

The need for a surgical airway is rapidly diminishing with the multitude of alternate airways that are available. This includes laryngeal mask airways, light wand stylets, combitubes, and endoscopic intubation. The need to be well trained in the use of all these techniques may be anxiety provoking and unnecessary. However, with their availability, it would be prudent for emergency clinicians to be familiar with at least 1 alternative airway technique to serve as an option prior to seeking a surgical/needle airway. Literature on the use of alternate airways in children has recently become more common.[174] The overall low incidence of cases requiring an alternate airway makes it difficult to design a study comparing the different modalities in the pediatric population.

Recent literature has shown the laryngeal mask airway (LMA) to be an effective tool for pediatric airways in elective surgery.[175,176] The use of the LMA in the ED and prehospital setting has also come under study.[177,178] The LMA is designed to be placed in a blind fashion and has a tip that essentially allows air to enter the trachea while occluding the esophagus. This occlusion does not protect the airway from aspiration. Pediatric and neonatal sizes are available. As an emergency alternative airway, there is an intubating design that allows the physician to place an endotracheal tube using the LMA as a guide. Further studies are required to endorse their routine use in the ED setting, but LMAs should certainly be considered as part of the difficult airway armamentarium.[179]

Surgical Airways

Despite even the best efforts, occasionally an airway cannot be secured. If one is unable to use endotracheal intubation or alternate airway measures, a surgical airway is necessary. Needle cricothyrotomy is recommended for younger children due to concerns that anatomical differences increase the complication rate of surgical cricothyrotomies. An actual age cut off has not been well established, but a lower cut off for surgical cricothyrotomy of between 5 and 12 years of age has been recommended.[180] The needle cricothyrotomy involves puncturing the cricothyroid membrane with a 14-gauge angiocath attached to a syringe, at a 45 degree angle caudally. The angiocath is then connected to 100% oxygen at 50 psi. Although this method provides adequate oxygenation, it provides poor ventilation. Surgical cricothyrotomy is recommended for older patients.

Foreign Body Removal

Aspirated foreign bodies are rare but imminently life threatening. Appropriate management consists of attempting to remove the foreign body with a finger sweep if the foreign body can be visualized, or if the object cannot be seen, using alternating

abdominal thrusts and back blows in the conscious child. Direct laryngoscopy and removal with Magill forceps should be attempted in the setting of severe respiratory distress or respiratory arrest. Emergency clinicians should be familiar with the use of Magill forceps. There are case reports of the successful use of Magill forceps to remove foreign bodies above and below the vocal cords.[181]

Pharmacologic Therapy

Bronchodilators

Bronchodilators are the cornerstone of therapy for acute asthma. Bronchodilators can be delivered as nebulized medications, via MDI, and IV. Please refer to the **Critical Appraisal Of The Literature** section for a more detailed discussion.

Vasoconstrictors

Nebulized racemic epinephrine is a well-established option in the treatment of croup when patients are stridulous at rest. Although there was controversy over the disposition of children treated with nebulized racemic epinephrine due to a feared "rebound" effect, recent studies have questioned the existence of this phenomenon. Patients may worsen as the epinephrine vasoconstriction diminishes, but there is no proven "rebound" effect.[182] A study by Ledwith concluded that patients can be safely discharged after 3 hours of receiving racemic epinephrine if symptoms have resolved.[183] There is no literature to support the traditional teaching that racemic epinephrine is superior to L-epinephrine due to the D-isomer preventing the adverse side effects. In fact, in a study by Waisman et al, patients that were randomized to racemic and L-epinephrine were found to have no differences in croup scores, heart rate, or blood pressure. This study used 5 mL of 1:1000 epinephrine.[184]

Anticholinergics

Nebulized anticholinergic medications are a recommended therapy in the treatment of acute severe asthma.[2] When used in conjunction with a beta-agonist, inhaled ipratropium has demonstrated improvement in pulmonary function and hospitalization rate in multiple studies.[21,22]

Steroids

For patients with acute asthma and croup, systemic steroids are key therapeutic interventions. Intrave-

Risk Management Pitfalls In The Treatment Of Difficulty Breathing

1. **"It can't be asthma – the child wasn't wheezing."**
   Children with asthma who are very sick may present with a "silent chest" due to very poor air exchange. The severe degree of bronchoconstriction seen in these patients is thought to obstruct airflow sufficiently to impede wheezing. Many times, the initiation of beta-agonist therapy with albuterol will result in the patient manifesting wheezing.

2. **"What do you mean he's now apneic? His respiratory rate was normal just a little while ago!"**
   As children progress from respiratory distress to respiratory fatigue, they will start to breathe more slowly. It can be dangerous to assume that a child who is breathing more slowly is clinically improving.

3. **"Congestive heart failure!? The baby didn't have rales."**
   Congestive heart failure in infants may not typically manifest with rales. Instead, assessing the presence of hepatomegaly on physical examination or noting a history of sweating during feeds will more likely identify cases of congestive heart failure in infants.

4. **"It couldn't be pertussis – the baby was not whooping."**
   Few infants with pertussis infection have the classis paroxysmal cough. Be suspicious of pertussis infection with a history of prolonged cough or apnea, in under-immunized infants.

5. **"How could this be a foreign body – there was no history, and the chest x-ray was clear?"**
   Often, a foreign body aspiration will not have an accompanying history, and a child will present with new onset wheezing (occasionally unilateral) without predisposing factors. A normal chest x-ray does not rule out a foreign body. A high index of suspicion is often necessary to make the diagnosis.

6. **"The patient's croup got better after the epinephrine treatment — so I sent her home."**
   Although the theoretical "rebound" effect of racemic epinephrine has not been substantiated in the literature, patients with croup and resting stridor require additional treatment and evaluation after the effects of the epinephrine have worn off.

nous, oral, and IM routes of a variety of preparations have all been shown to be effective. Evidence to date does not support the utility of steroids in patients with bronchiolitis. The role of inhaled corticosteroids in the management of acute asthma is of unproven benefit. Currently, national guidelines recommend oral steroids in initial management of significant asthma exacerbations.

Antibiotics

The recommendations for antibiotic therapy in pediatric patients with lower respiratory tract infections vary. Recently published studies comparing efficacy of different agents (amoxicillin, amoxicillin-clavulanate, azithromycin, erythromycin estolate) found similar and excellent treatment success.[185] This is most likely due to the fact that most pediatric outpatient pneumonia is of viral etiology. For patients requiring inpatient care with community-acquired pneumonia, antibiotics that treat pneumococcus and atypical organisms should be chosen. A palatable second- or third-generation oral cephalosporin (or parenteral) and a macrolide antibiotic would be reasonable. Special scenarios must be considered, such as patients with tracheostomies who will require coverage for *Pseudomonas* species, while older children with neurological deficits or a history of aspiration pneumonia will need coverage for anaerobic and gram-negative flora.

Special Circumstances

H1N1 Influenza

The federal government recognizes that children represent an at-risk population with special needs, as seen by their inclusion in the Pandemic and All-Hazards Preparedness Act.[186] The H1N1 influenza outbreak that began in April of 2009 allowed federal, state, and local governments to demonstrate their ability to respond to a crisis that has disproportionately affected the pediatric population.[187] Although the majority of children infected with this virus require only supportive care, antiviral therapy for certain populations is necessary. Current recommendations on treatment can be found at the CDC's website (http://www.cdc.gov/h1n1flu) as they can rapidly change as new information is gathered. A subset of patients is high risk and requires treatment with antivirals. This group includes many of the diseases discussed in this article including asthma, congenital heart disease, neurological/neuromuscular diseases, chronic lung disease, immunosuppression, and sickle cell anemia. The high-risk group also includes those who are < 2 years of age, are pregnant, or have severe illness. Early treatment appears to be most beneficial. Vaccination against seasonal and H1N1 influenza is also recommended for children > 6 month of age.[188] The ability of the government to disseminate and emergency clinicians to respond to real-time information enables the best care for children. Healthcare providers need to be able to respond quickly and appropriately to new challenges such as this pandemic.

Cystic Fibrosis

Cystic fibrosis is the most common inherited genetic disorder in Caucasians. New advances in treatment have improved life span and prolonged pulmonary function. Exacerbations of cystic fibrosis can present as increased sputum production and work of breathing with or without fever. Pneumonia in cystic fibrosis patients is usually secondary to *Staphylococcus aureus* in younger children and *Pseudomonas aeruginosa* in older children and teenagers. Of special concern in these patients is infection with Burkholderia cepacia; this organism is highly resistant and can signify advanced disease. The management of a cystic fibrosis exacerbation includes bronchodilators, steroids, chest physiotherapy, and postural drainage as well as broad-spectrum IV antibiotic therapy. Children with long-standing illness typically have multiple drug resistant species. Consultation with pediatric pulmonology and admission are generally required.[189]

Sickle Cell Anemia

Acute chest syndrome (ACS) is defined as a new infiltrate on chest x-ray associated with 1 or more of the following: fever, cough, dyspnea, sputum production, tachypnea, or hypoxia.[190] Acute coronary syndrome is the second most common cause of hospitalization and a significant cause of mortality in children with sickle cell anemia. The specific etiology is unclear and likely a multi-factorial syndrome of infection and pulmonary infarction. The clinical symptoms vary with age. Young children (ages 2-4) typically have fever and cough, whereas older children may also have chest pain, shortness of breath, and hemoptysis. Morris et al found that the prediction of ACS in children with fever was grossly underestimated by clinicians likely because there were few clinical symptoms of the underlying pulmonary disease. Therefore, the study recommended routine chest x-ray for those patients with sickle cell anemia presenting with fever.[191] Vichinsky et al found that nearly 50% of patients with ACS were admitted to the hospital for another reason, leading to a delay in diagnosis and treatment.[190] The management of ACS includes supplemental oxygen, gentle IV fluid supplementation, IV antibiotic therapy (typical pathogens include *Streptococcus* pneumonia, *Haemophilius influenzae*, and atypicals) with a second- or third-generation cephalosporin and a macrolide.[192] Both simple and exchange transfusions have been advocated for the treatment of ACS. Two adult studies showed that transfusing to a hemoglobin of 10 g/

dL may be as beneficial as more aggressive transfusion methods.[190,193]

Bronchopulmonary Dysplasia / Chronic Lung Disease

Advances in neonatal/perinatal medicine have created a large cohort of formerly premature infants. Those premature infants who required prolonged ventilatory support are at high risk of developing bronchopulmonary dysplasia, a form of chronic lung disease. The treatment for children with bronchopulmonary dysplasia in respiratory distress is generally the same as those with asthma: inhaled bronchodilators, corticosteroids, IV fluids, and supplemental oxygen with intubation for impending respiratory failure. Exacerbation of their disease can be triggered by simple upper respiratory infections. Important caveats in treating these patients include an awareness that these children can proceed to respiratory failure more rapidly due to limited reserves and that these children may respond to diuretic therapy such as furosemide.[194]

Immunosuppressed Children

Chronic immune suppression in children can be secondary to a multitude of etiologies. These may be viral induced such as HIV, congenital immune deficiencies, or systemic illnesses requiring immunotherapy. In general, the presence of any respiratory complaints should alert the physician to investigate the possibility of lower respiratory tract infection. One must also consider a broader differential diagnosis for the types of organisms (bacterial, viral, and fungal) that can infect these already compromised patients. Management should be aggressive with broad-spectrum antibiotics, consideration of anti-fungals, and the involvement of pediatric sub-specialists.

Steroid Dependent Asthmatics

Children with severe persistent asthma or children who present to the ED in distress who are currently on systemic steroid therapy pose difficult management questions for the emergency clinician. There has been little research on the ED management of this subgroup reported. However, it seems prudent to be more aggressive in managing these patients and to be careful with their disposition. They should be considered immunosuppressed and treated with consultation of pulmonary sub-specialists.

Neuromuscular Disorders

Respiratory illness in children with neuromuscular disease can be potentially devastating and often life threatening. These children may not be able to generate the power for increased work of breathing in the presence of infection. Mucous plugging can precipitate respiratory distress and can be treated with chest physical therapy.[195] They also may develop chronic respiratory insufficiency as a symptom of their underlying disease. Ventilatory assistance is often required.

Controversies / Cutting Edge

Noninvasive Ventilation

Noninvasive ventilation has been used as both a bridge to a definitive airway and as definitive treatment for pediatric respiratory failure. A variety of different methods have been used including high-flow nasal cannula therapy (HFNC), CPAP, and BiPAP. Many small studies and case series suggest the benefits of these forms of respiratory support in children.[196-199] Continuous positive airway pressure has gained acceptance as noninvasive respiratory support for neonates.[200] One larger study compared intubation rates for children with bronchiolitis before and after the advent of HFNC therapy in the PICU and showed a 68% decrease with its use. This may prove to be a promising easy technique, although the need for sedation to increase compliance and inability to generate adequate pressure have been raised as concerns.[199,201] Overall, noninvasive ventilation in adults has been shown to decrease morbidity and mortality, ICU length of stay, and healthcare costs and could prove an equal benefit in the pediatric population.[202,203]

Isomeric Albuterol

Isomeric albuterol (levalbuterol, Xopenex®) has come onto the market. There is a theoretical benefit of removing the s-isomer, but the significance of this change remains unproven. Carl et al and Schreck et al compared the efficacy of albuterol and levalbuterol on hospitalization rate and found decreased hospitalization rate in the levalbuterol group.[204,205] Four other more-recent studies, 3 of which were double-blind randomized controlled trials, have failed to show a significant clinically important benefit from levalbuterol.[206-208] The fourth study showed that using continuous levalbuterol provided no significant advantage over racemic albuterol.[209] The increased cost of this isomeric version without proven benefit prevents any recommendation for substitution of the racemic form. Patients with limited ability to tolerate tachycardia, such as cardiac patients, may benefit from levalbuterol, but this has not been adequately studied.

Helium Oxygen Mixture

Helium oxygen mixture is another innovative therapeutic modality for patients with airway obstruction and inflammation. The addition of helium gas to oxygen provides a more laminar airflow, theoretically easing the work of breathing through narrowed airways. Specific disease states where its use has been evaluated include asthma, croup, and in

the presence of inhaled foreign bodies. In order to achieve the laminar effect of helium, the mixture must at least be 70% helium and 30% oxygen. If oxygenation is an issue for the patient, this mixture of helium and oxygen may not provide sufficient supplemental oxygen.

Ketamine

Ketamine has become a recommended agent for procedural sedation in pediatric patients.[210] Ketamine protects airway reflexes and has a bronchodilatory effect. This benefit makes it a good choice for sedation for intubation.

Disposition

The appropriate disposition of patients with respiratory distress is a multi-factorial decision. Generally speaking, in order to be safely discharged home patients must no longer be in respiratory distress, have acceptable oxygenation in room air, be able to tolerate fluids, and have a clear home therapy plan. Ancillary factors to consider include adequate social support structure, means of transportation back to the ED if the need arises, and appropriate access to follow-up care.

For cooperative asthmatics > 5 years of age, documentation of an improving trend in peak expiratory flow rates after a period of observation in the ED may be helpful despite some evidence that a normal peak flow can be falsely reassuring.[211] Since asthma is a chronic condition, access to a primary care provider for follow up is of utmost importance. Patients on continuous nebulized treatments, beta-agonist infusions, or heliox therapy require ICU admission. Patients who minimally respond to ED therapy or require frequent monitoring may also require ICU level of care. Anticipatory guidance for patients with croup/bronchiolitis is essential to a successful disposition. Informing parents of the expected clinical course, exacerbating factors, and signs of deterioration is an important part of management.

Infrequently, a patient will present with recurrent diagnoses of lower respiratory tract infection or refractory wheezing. The astute clinician should be aware of the possibility of an underlying congenital syndrome such as congenital heart disease, an anatomic airway or vascular anomaly, or an undiagnosed foreign body. A more thorough work-up should be initiated for these patients.

Summary

The evaluation and management of children with difficulty breathing is both challenging and rewarding. Knowing the most up-to-date evidence for the appropriate treatment of the broad range of etiologies is critical to improving outcomes. This review highlights evidenced-based medicine that encourages providing treatments that have proven benefit such as the early administration of steroids for asthma and croup, while avoiding unproven treatments such as steroids in bronchiolitis. Performing basic interventions such as allowing the child to maintain a position of comfort and administering supplemental oxygen must proceed swiftly and concomitantly as the appropriate history, examination, and definitive work-up and care is taking place. An organized approach such as the one presented in this review will assist the emergency clinician in practicing thorough and effective medicine.

References

Evidence-based medicine requires a critical appraisal of the literature based on 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.

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CME Questions

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1. Which of the following statements about bronchiolitis is true?
a. Bronchiolitis in viral lung infections is caused by several viruses.
b. Epinephrine should be administered to all infants in the ED with bronchiolitis.
c. Inhaled bronchodilators are effective in all cases of bronchiolitis in the ED.
d. Steroids shorten the hospital stay by several days in cases of bronchiolitis.
suspected pneumothorax
d. to confirm the diagnosis of bronchiolitis

2. A capillary blood gas may be helpful in:
a. Identifying a metabolic etiology for respiratory distress
b. Deciding the timing for intubation
c. Deciding which asthmatic patients needs hospital admission
d. Determining the administration of racemic epinephrine in croup

3. The next step in the management of foreign body aspiration in a child who goes into respiratory arrest in the ED is:
a. Blind finger sweeps
b. Abdominal thrusts followed by back blows
c. Direct laryngoscopy and attempted removal by Magill forceps
d. Intubation

4. Exacerbations of symptoms of cystic fibrosis include:
a. Fever
b. Increased sputum production
c. Increased work of breathing
d. All of the above

5. Which of the following is the most common cause of difficulty breathing in children with sickle cell anemia?
a. Acute chest syndrome
b. Diaphragmatic hernia
c. Salmonellae osteomyelitis
d. Pneumocystis pneumonia

6. Which of the following statements about the current asthma literature is true?
a. Anticholinergic medication is contraindicated in pediatric asthma.
b. Ketamine should be given to all children with asthma in the ED.
c. Magnesium sulfate has clearly been shown to be effective in mild asthma.
d. Steroids are a part of standard emergency department care of acute asthma.
e. Theophylline, administered orally, is standard emergency department therapy.

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
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:
- 1 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

Significantly modified from: The Emergency Cardiovascular Care Committees of the American Heart Association and representatives from the resuscitation councils of ILCOR: How to Develop Evidence-Based Guidelines for Emergency Cardiac Care: Quality of Evidence and Classes of Recommendations; also: Anonymous. Guidelines for cardiopulmonary resuscitation and emergency cardiac care. Emergency Cardiac Care Committee and Subcommittees, American Heart Association. Part IX. Ensuring effectiveness of community-wide emergency cardiac care. *JAMA.* 1992;268(16):2289-2295.

Physician CME Information

Date of Original Release: July 1, 2011. Date of most recent review: June 10, 2010. Termination date: July 1, 2014.

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Target Audience: This enduring material is designed for emergency medicine physicians, physician assistants, nurse practitioners, and residents.

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1.	[a]	[b]	[c]	[d]	[e]
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3.	[a]	[b]	[c]	[d]	[e]
4.	[a]	[b]	[c]	[d]	[e]
5.	[a]	[b]	[c]	[d]	[e]
6.	[a]	[b]	[c]	[d]	[e]
7.	[a]	[b]	[c]	[d]	[e]
8.	[a]	[b]	[c]	[d]	[e]
9.	[a]	[b]	[c]	[d]	[e]
10.	[a]	[b]	[c]	[d]	[e]
11.	[a]	[b]	[c]	[d]	[e]
12.	[a]	[b]	[c]	[d]	[e]
13.	[a]	[b]	[c]	[d]	[e]
14.	[a]	[b]	[c]	[d]	[e]
15.	[a]	[b]	[c]	[d]	[e]
16.	[a]	[b]	[c]	[d]	[e]

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