Acute Bronchiolitis: Assessment and Management in the Emergency Department

Abstract

Acute bronchiolitis is the most common lower respiratory tract infection in young children that leads to emergency department visits and hospitalizations. Bronchiolitis is a clinical diagnosis, and diagnostic laboratory and radiographic tests play a limited role in most cases. While studies have demonstrated a lack of efficacy for bronchodilators and corticosteroids, more recent studies suggest a potential role for combination therapies and high-flow nasal cannula therapy. Frequent evaluation of patient clinical status including respiratory rate, work of breathing, oxygen saturation, and the ability to take oral fluids are important in determining safe disposition. This issue reviews the literature to provide evidence-based recommendations for effective evaluation and treatment of pediatric patients with acute bronchiolitis.
Case Presentations

As your shift is winding down at 4 AM, a mother brings in her 9-month-old infant, whom she describes as “gasping for air.” The baby has had a runny nose and cough for a few days as well as a low-grade fever, but now he is breathing rapidly and wheezing, with lower intercostal retractions. The mother states that the infant has had wheezing in the past, and she asks if he might have asthma since “it runs in the family.” She also indicates that in the last 12 hours, he has not taken his usual amount of fluids. His oxygen saturation level is 87% on room air. You begin to think… should I treat this as reactive airway disease, asthma, or bronchiolitis? When should I give the patient albuterol, nebulized epinephrine, or oxygen? Does the infant need steroids? You also wonder whether this patient is going to tire and require assisted ventilation or whether there are any other alternatives to intubation.

It is the middle of influenza season, and the waiting room is full of coughing, sniffing children. Your patient, a 6-week-old boy, presents with rhinorrhea and poor feeding for the last 2 days. The mother states that he is not breastfeeding as well as usual due to his congestion. She says there is no family history of respiratory problems. The boy was born prematurely at 29 weeks’ gestation, requiring admission to the NICU for 2 weeks for respiratory support. His oxygen saturation level is 91% to 92% on room air. Should you give supplemental oxygen? Should you send respiratory viral panels? Does the infant need to be admitted?

Introduction

Bronchiolitis is the most common lower respiratory tract infection (LRTI) in infants and young children aged < 2 years. Each year in the United States, LRTIs cause > 100,000 hospitalizations of children aged < 1 year. In particular, respiratory syncytial virus (RSV) is the leading cause of hospitalization in this age group. A study published in 2016 that summarized trends in bronchiolitis hospitalizations in the United States reported an average cost of $8530 per admission, or $1.7 billion nationwide.1 Although there was a decrease in bronchiolitis hospitalizations between 2000 and 2009 (from 17.9 to 14.9 per thousand, respectively), bronchiolitis remains a major healthcare financial burden.1,2

Despite the high prevalence of bronchiolitis, it is a clinical diagnosis without a common international definition. In 2014, the American Academy of Pediatrics (AAP) defined bronchiolitis as “rhinitis, tachypnea, wheezing, cough, crackles, use of accessory muscles, and/or nasal flaring in infants.”3 Children presenting with these symptoms are often given numerous diagnoses such as reactive airway disease, wheezing, cough, asthma, or pneumonia, as well as bronchiolitis.4 A study by Jartti et al suggested that the diagnosis of bronchiolitis should be restricted either to children aged < 24 months who are having their first episode of wheezing or to children aged < 12 months.5

This issue of Pediatric Emergency Medicine Practice uses evidence-based medicine to recommend strategies for effective evaluation and treatment of bronchiolitis in pediatric patients. Novel treatments for acute bronchiolitis such as nasal continuous positive airway pressure (nCPAP), high-flow nasal cannula (HFNC) therapy, nebulized hypertonic saline, and heliox also will be discussed.

Critical Appraisal of the Literature

A search of articles published on bronchiolitis from 1970 to 2019 was performed using Ovid MEDLINE® and PubMed. Terms used in the search included wheezing, bronchiolitis, lower respiratory tract infection, RSV, infant respiratory distress, bronchiolitis guidelines, and steroids. More than 200 articles were analyzed, providing the background for further review. In addition, the Cochrane Database of Systematic Reviews was consulted. Major current international guidelines for the diagnosis and management of bronchiolitis were also reviewed and compared in relation to recommendations pertinent to the assessment and management of acute bronchiolitis in the emergency department (ED).3,6–11

There is significant variation in the bronchiolitis literature in the definition of bronchiolitis, the clinical scoring systems, and outcome measures. Additionally, differing cutoff ages for bronchiolitis, as well as the lack of a valid clinical scoring system that correlates with clinically significant improvement and the inclusion of testing for RSV or other viruses in the diagnosis complicate a review and comparison of the literature. Although there are excellent published guidelines to help clinicians address this common condition, they often exclude the group at high risk for severe bronchiolitis (eg, patients who are at risk for serious complications, such as apnea, and who may need ventilatory support). The 2014 AAP clinical practice guidelines provide recommendations on the diagnosis, management, and prevention of bronchiolitis.

Pathophysiology

Bronchiolitis is a viral infection of the small airways. Infection of the bronchial respiratory and ciliated epithelial cells produces increased mucus secretion, cell death, and sloughing, followed by a peribronchial lymphocytic infiltrate and submucosal edema. This leads to small-airway narrowing and obstruction. Hypoxia can occur due to the ventilation/perfusion mismatch caused by decreased ventilation of a portion of the lungs. The degree of obstruction may vary as these areas are cleared, accounting for a rapidly
Etiology

Understanding of the viruses that cause bronchiolitis has increased greatly with the availability of sensitive diagnostic tests that use molecular amplification techniques. RSV continues to account for the majority of cases (50%-80%). However, RSV is a rare pathogen in older children hospitalized with bronchiolitis because nearly all people are infected with RSV within the first 2 years of life, and the initial RSV infection is usually the most severe. In the United States, annual epidemics of RSV typically begin in the late fall and peak between November and March, but regional seasonality does exist. Metapneumovirus (HMPV) accounts for an additional 3% to 19% of bronchiolitis cases and appears to have a clinical course similar to that of RSV, with most children infected during annual wintertime epidemics and a subset developing bronchiolitis. Other causes of bronchiolitis include the parainfluenza viruses (primarily parainfluenzavirus 3), the influenza viruses, adenoviruses, coronaviruses, rhinoviruses, and enteroviruses.

The role of rhinoviruses in bronchiolitis is unclear compared to their well-documented role in triggering exacerbations of wheezing in patients with asthma. A study by Jartti et al focused on viral etiologies in young children with acute asthma and found that rhinovirus was an important agent (ie, it was identified in 65% of children aged 1-2 years and in 82% of children aged ≥3 years). New molecular diagnostic techniques have made it possible to determine whether young children with bronchiolitis and other acute respiratory illnesses are infected with more than 1 virus. The natural course of bronchiolitis can be impacted by the presence of more than 1 pathogen, such as the association of RSV/HMPV or RSV/rhinovirus. A prospective study of children aged <5 years hospitalized with RSV infection revealed a co-infection rate of 6%. Whether concomitant infections increase the severity of bronchiolitis remains controversial. One study found that dual RSV/HMPV infections were associated with a 10-fold increase in the risk of the need for mechanical ventilation. In a study that evaluated the association between infection with multiple viruses and disease severity in children aged <2 years, co-infection was present in 41% of the children. Interestingly, for RSV-infected children aged <3 months, disease severity was not associated with the number of detected viruses. The authors of that study concluded that disease severity in children with bronchiolitis is not associated with infection by multiple viruses, and that other factors (eg, age) contribute to disease severity to a greater extent. Of note, polymerase chain reaction (PCR) positivity can extend beyond the acute phase of the viral infection, which has the potential to impact the results of these studies, depending on the timing of the testing.

Table 1. Differential Diagnosis for Wheezing in Infancy

<table>
<thead>
<tr>
<th>Emergent Causes</th>
<th>Nonacute Causes</th>
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<tr>
<td>Infection: pneumonia, chlamydia, pertussis</td>
<td>Congenital anomaly: tracheoesophageal fistula, bronchogenic cyst, laryngotracheomalacia</td>
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<tr>
<td>Foreign body: aspirated or esophageal</td>
<td>Gastroesophageal reflux disease</td>
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<tr>
<td>Cardiac anomaly: congestive heart failure, vascular ring</td>
<td>Mediastinal mass</td>
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<tr>
<td>Allergic reaction</td>
<td>Cystic fibrosis</td>
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Cough, tachypnea, and wheezing are typical symptoms of bronchiolitis. Although wheezing is the prominent presentation of acute bronchiolitis, many other common and critical diseases should also be considered when infants and young children present with wheezing. It is important to differentiate wheezing from stridor, as stridor has an independent differential diagnostic list, including potential emergent conditions such as epiglottitis. Clues from the medical history may facilitate the correct diagnosis. For example, vomiting and wheezing and coughing associated with feeding may indicate gastroesophageal reflux disease (GERD) or tracheoesophageal fistula, and can be evaluated by a pediatric specialist if symptoms are severe. In most cases of GERD, the diagnosis can be made from the history and physical examination. Feeding modifications can be initiated in the ED and monitored by the pediatric specialist if symptoms are severe.

In a study that evaluated the association between RSV and infant mortality, the rate of RSV infection was 11% in infants who died. The association between RSV and mortality was stronger in infants <3 months of age, with a rate of 21% in this group. This study highlights the importance of early intervention in the treatment of RSV-infected infants.
primary care provider. When wheezing is associated with positional changes, tracheomalacia or anomalies of the great vessels may be present. If a vascular ring is suspected clinically (eg, when wheezing is exacerbated by neck flexion and relieved by neck hyperextension), further investigation may be warranted. Outpatient workup can include chest radiograph, angiography, barium swallow, bronchoscopy, computed tomography (CT), or magnetic resonance imaging (MRI). Cystic fibrosis or immunodeficiency should be suspected when the child has a history of multiple respiratory tract illnesses and a failure to thrive. Further workup by the child’s primary care provider or a specialist can include ciliary function testing, immunoglobulin levels, and sweat chloride testing. Wheezing in the presence of heart murmurs, cardiomegaly, cyanosis without respiratory distress, and exertion and sweating associated with feeding might indicate cardiac diseases. The sudden onset of wheezing and choking suggests foreign body aspiration.

Asthma

It is challenging to distinguish reactive airway disease and asthma from bronchiolitis in young children. To differentiate between the diagnosis of bronchiolitis and asthma, some investigators recommend that the diagnosis of bronchiolitis should apply to wheezing only in patients aged ≤ 12 months. In the past, some investigators have extended the cutoff for the upper age limit for making the diagnosis of bronchiolitis from 24 to 36 months. Estimates vary, but the majority of children diagnosed with asthma (80%-90%) had symptoms before the age of 6 years, with 70% of children experiencing asthma-like symptoms before the age of 3 years.

Castro-Rodriguez et al developed the modified Asthma Predictive Index to differentiate between asthma and recurrent wheezing with bronchiolitis in younger children. They developed 2 indices for the prediction of asthma, the stringent index and the loose index.29

The stringent index requires frequent wheezing in the first 3 years of life plus 1 of 2 major criteria (history of a physician diagnosis of asthma or physician diagnosis of atopic dermatitis) or 2 of 3 minor criteria (a diagnosis of allergic rhinitis in the child, eosinophilia [ie, eosinophil count ≥ 4% of the total white blood cells], or wheezing apart from colds). Frequency of wheezing is determined by asking the parent(s) whether the child’s chest has ever sounded wheezy or whistling and to rate how often the child has wheezed (on a scale of 1, “very rarely,” to 5, “on most days”). Patients are considered “frequent wheezers” if parents report a value > 3 on the scale.

The loose index for the prediction of asthma requires any wheezing during the first 3 years of life plus 1 of the major criteria or 2 of the minor criteria. According to Castro-Rodriguez et al, children with a positive loose index were up to 5.5 times more likely between the ages of 6 and 13 years to have active asthma than children with a negative loose index. Children with a positive stringent index were up to 9.8 times more likely than children with a negative stringent index to have asthma later in childhood.29

In one study, children aged < 6 months who were hospitalized for bronchiolitis (caused by various viruses) were followed prospectively to evaluate outcomes, with special focus on asthma at preschool age (mean age, 6.5 years). Twenty-one children (12.7%) had asthma at preschool age: 8.2% were children with a former RSV infection, and 24.7% were non–RSV-infected patients (P = .01). In adjusted analyses, independently significant early-life risk factors for asthma were atopic dermatitis, non–RSV bronchiolitis, and maternal asthma.30

Prehospital Care

The goals of prehospital care for the infant or young child with bronchiolitis must include timely assessment and recognition of the severity of the disease and initiation of appropriate treatment. Young age (ie, < 2 months) and a history that includes prematurity, chronic lung disease, or any cardiac or immune deficiencies as well as physical examination results including general appearance, vital signs, mental status, and work of breathing (eg, tachypnea, accessory muscle use, nasal flaring, grunting) can guide the prehospital provider in patient assessment. Special attention should be given to the occurrence of apnea spells, particularly if the caregiver reports a previous episode, and if the patient is a neonate or was premature with a corrected gestational age < 48 weeks. Cardiorespiratory monitoring and positioning of the infant or young child to facilitate respiratory efforts (ie, placing the patient in an upright posture) are essential. In addition, treatment should include nasal suctioning and administration of oxygen if the patient’s oxygen saturation level is ≤ 90%.

Emergency Department Evaluation

History

Risk Factors for Severe Bronchiolitis

It is critical for emergency clinicians to inquire about the patient’s risk factors for severe bronchiolitis, which include persistently increased respiratory effort, apnea, and the need for intravenous (IV) hydration, supplemental oxygen, or mechanical ventilation. Several studies have associated premature birth (< 35-37 weeks’ gestation) and younger age (< 6-12 weeks) with an increased risk of severe bronchiolitis.31–33

Other conditions predisposing the patient to severe disease or mortality include underlying respiratory illnesses such as bronchopulmonary dysplasia (also known as chronic lung disease), cystic fibrosis, and
congenital anomalies. Hemodynamically significant congenital heart disease, an immune deficiency such as HIV infection or organ or bone marrow transplant, and congenital immune deficiencies are also risk factors.34,35 (See Table 2.)

The vast majority of studies addressing the risk factors for severe bronchiolitis and outcomes such as the need for mechanical ventilation and intensive care have involved hospitalized patients, which is a small subset of all children with bronchiolitis seen in the ED. The infrequent occurrence of these adverse events limits the power of these studies to predict bronchiolitis severity. In a recent study, multivariable predictors of escalated care were age < 2 months, oxygen saturation < 90%, nasal flaring and/or grunting, apnea, retractions, dehydration, and poor feeding. A risk score including these variables can stratify the risk of escalated care in the ED, which could help with treatment and disposition decisions.36

Risk Factors for Apnea
Several factors have been identified to predict which patients with bronchiolitis are at risk for the development of apnea in the course of their illness. (See Table 2.) These factors include young age, prematurity, a history of apnea of prematurity, and presentation with apnea.37-41 Of note, these studies have focused on patients with confirmed bronchiolitis due to RSV, which could explain the high rates of apnea (16%-25%) reported in hospitalized patients with RSV infection.

In a 2006 retrospective study, Willwerth et al reported the rate of apnea in young infants with clinically diagnosed bronchiolitis and offered a set of criteria for identifying high-risk patients. Children were considered to be at high risk for apnea if: (1) they were full-term at birth and were younger than 1 month, (2) they were preterm at birth (< 37 weeks' estimated gestation) and were younger than 48 weeks post conception, or (3) the child's parents or a clinician had already witnessed an apnea episode with this illness before admission.42 A small percentage of admitted infants with bronchiolitis developed apnea (2.7%; 19 out 691 infants), and all were identified as high-risk patients using the high-risk criteria. Approximately 62% of the patients who did not develop apnea were classified by these criteria as being at low risk. Because the study included only hospitalized patients, this set of criteria cannot be applied to the patients with bronchiolitis who were discharged from the ED. The rate of apnea in this study is lower than the reported apnea rate of 16% to 25% in the RSV bronchiolitis study, which could be due to the fact that RSV testing was performed on disproportionately younger or sicker patients with bronchiolitis, a group naturally at higher risk of developing apnea.42 In a study that evaluated risk factors for inpatient apnea among children hospitalized with bronchiolitis, a similar apnea risk was found across the major viral pathogens, including adenovirus and HMPV.43

Despite the fact that the rate of apnea in hospitalized infants with bronchiolitis is low, these clinical risk criteria can help emergency clinicians make more informed decisions about which patients require monitoring or admission, by identifying low-risk infants whose risk of apnea is < 1%.

Physical Examination
Serial examination of patients' respiratory status are very important in assessing overall patient status and reflecting variability in the disease state, from mucus plugging to progressive respiratory distress due to lower airway obstruction. Important elements of the physical examination include respiratory rate, increased work of breathing as evidenced by accessory muscle use and/or retractions, and auscultation findings such as wheezes or crackles. The impact of respiratory symptoms on feeding and hydration, particularly in young infants, is also critical.

Respiratory Rate
Tachypnea, defined as a respiratory rate > 70 breaths/min in infants, has been associated with increased risk for severe bronchiolitis in some studies, but not in others.32,44 Additionally, tachypnea may

<table>
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<tr>
<th>Table 2. Risk Factors for Severe Bronchiolitis and Apnea</th>
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<tr>
<td><strong>Risk Factors for Severe Bronchiolitis:</strong></td>
</tr>
<tr>
<td>• Age: &lt; 6-12 weeks31-33</td>
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<tr>
<td>• Prematurity: &lt; 35-37 weeks' gestation31-33</td>
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<tr>
<td>• Underlying respiratory illness such as bronchopulmonary dysplasia3</td>
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<tr>
<td>• Significant congenital heart disease; immune deficiency including HIV, organ or bone marrow transplants, or congenital immune deficiencies34,35</td>
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<td>• Altered mental status (impending respiratory failure)3</td>
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<td>• Dehydration due to inability to tolerate oral fluids3</td>
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<td>• Ill appearance32</td>
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<tr>
<td>• Oxygen saturation level ≤ 90%3</td>
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<tr>
<td>• Respiratory rate: &gt; 70 breaths/min or higher than normal rate for patient age3,32</td>
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<tr>
<td>• Increased work of breathing: moderate to severe retractions and/or accessory muscle use3</td>
</tr>
<tr>
<td>• Nasal flaring3</td>
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<tr>
<td>• Grunting3</td>
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| **Risk Factors for Apnea:** |
| • Full-term birth and < 1 month of age40,42 |
| • Preterm birth (< 37 weeks' gestation) and age < 2 months post birth31-33,42 |
| • History of apnea of prematurity3 |
| • Emergency department presentation with apnea42 |
| • Apnea witnessed by a caregiver42 |

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serve as a risk factor for development of dehydration with bronchiolitis, due to difficulty taking oral fluids with an excessively elevated respiratory rate. The respiratory rate in otherwise healthy children changes considerably over the first year of life, decreasing from a mean of approximately 50 breaths/min in full-term newborns to approximately 40 breaths/min at 6 months and 30 breaths/min at 12 months.\(^45,46\) Counting the respiratory rate for 1 minute may be more accurate than extrapolating measurements from shorter periods.\(^47\) The absence of tachypnea correlates with the lack of LRTI or pneumonia (viral or bacterial) in infants.\(^48\)

The Respiratory Distress Assessment Instrument\(^49\) is reliable with respect to scoring but has not been validated for clinical predictive value in patients with bronchiolitis. There is no standard clinical score to assess bronchiolitis, and many treatment trials use different variables to assess a medication’s impact on the course of bronchiolitis, such as respiratory rate, respiratory effort, severity of wheezing, and oxygenation. This was evident in a report by the Agency for Healthcare Research and Quality, in which 43 of 52 treatment trials used different clinical scoring systems, making comparison between these studies very difficult.\(^50\)

**Oxygen Saturation**

Oxygen saturation, as measured by pulse oximetry, is among the measures most strongly correlated with outcomes of patients with bronchiolitis. In a 2008 prospective multicenter study, a pulse oximetry level of \(< 94\%\) in the ED was associated with a \(> 5\)-fold increase in the likelihood of hospitalization.\(^51\) According to the 2014 AAP bronchiolitis guidelines, “clinicians may choose not to administer supplemental oxygen if the oxyhemoglobin saturation exceeds 90% in infants and children with a diagnosis of bronchiolitis,” but this recommendation was based on low-level evidence.\(^3\) In addition, evidence indicated that a pulse oximetry reading of 90% tends to overestimate the actual oxygen saturation in children (mean bias 4.2% between 86% and 90% and 1.8% between 91% and 95%).\(^52\)

**Diagnostic Studies**

In the acute care setting, acute bronchiolitis is primarily a clinical diagnosis. Diagnostic testing (eg, chest radiography, virologic testing, complete blood cell count, and urinalysis) is not routinely recommended for infants with bronchiolitis.

**Radiographic Imaging**

Although radiographs may be useful in the ED when severe disease requires further evaluation or if there is concern for foreign body aspiration, pneumonia, or congestive heart failure based on the history and physical examinations findings, current evidence does not support routine use of radiography in children with bronchiolitis.\(^53\) Two studies indicated that the presence of consolidation and atelectasis on a chest radiograph was associated with an increased risk for severe disease;\(^31,32\) however, a different study showed no correlation between chest radiograph findings and baseline disease severity.\(^54\)

Obtaining a chest radiograph could, however, affect the decision to start antibiotics. Numerous prospective studies, including a randomized trial, have shown that children with a suspected LRTI for whom radiographs were obtained were likely to receive antibiotics, without any difference in time to recovery.\(^35,36\) A subsequent prospective study of 265 children aged 2 to 23 months who presented to the ED with bronchiolitis analyzed the use of routine radiography in patients with a simple form of the disease (defined in a child as coryza and cough accompanying a first episode of wheezing, without underlying illness).\(^57\) The authors of that study identified findings inconsistent with bronchiolitis in only 2 cases, and in neither case did the findings change short-term management. Clinicians were more likely to treat patients with antibiotics when ordering radiographs despite the fact that the radiographic findings did not support such treatment.\(^57\)

**Viral Testing**

Identification in the ED setting of the causative agent of bronchiolitis has minimal effect on management. In addition, rapid viral antigen testing has variable sensitivity and specificity, depending on the test used and its timing in relation to the respiratory season.\(^58\) Emergency clinicians are most likely to obtain viral testing when encountering infants in the first few months of life who present with fever and typically recognized signs and symptoms of bronchiolitis. While this is not recommended in the bronchiolitis guidelines, the 2016 ACEP fever guidelines note that positive viral testing can impact further workup of fever for a serious bacterial infection (SBI).\(^59\) A study of febrile infants aged \(< 60\) days with bronchiolitis and/or an RSV infection demonstrated that, although the overall risk of SBI in patients aged \(< 28\) days was significant, the risk was not different between RSV-positive and RSV-negative groups (10.1% vs 14.2%, respectively). All SBIs in children aged between 28 and 60 days with RSV-positive bronchiolitis were urinary tract infections (UTIs). The rate of UTIs in the RSV-positive group was significantly lower than the rate in the RSV-negative group (5.5% vs 11.7%, respectively).\(^60\) In another study of 2396 infants with RSV bronchiolitis, 69% of the 39 patients with an SBI had a UTI.\(^61\) Therefore, limited SBI testing can be considered in febrile infants with clinical or laboratory-proven bronchiolitis. A recent review spanning all age groups found a 0.8% prevalence of UTI in infants with bronchiolitis.\(^62\)
Treatment

Despite the extensive literature on bronchiolitis and the revised AAP guideline on the assessment and treatment of bronchiolitis,3 the treatment of bronchiolitis remains controversial. This is particularly true for severe bronchiolitis, due to a paucity of research on the treatment of severe bronchiolitis.

Oxygen Supplementation

Pulse oximetry has been adopted into the clinical assessment of children with bronchiolitis on the basis of data that show that it can reliably detect hypoxemia that is not detected on physical examination.63 Even though transient decreases to a peripheral capillary oxygen saturation (SpO2) level < 89% do occur in healthy infants, most have an SpO2 level > 95% on room air.44,65 Due to pathological changes in the airway of patients with bronchiolitis (such as airway edema and sloughing of respiratory epithelial cells) mismatching of ventilation and perfusion and subsequent reductions in oxygenation can occur. According to the oxygen dissociation curve, when the SpO2 level is > 90%, large increases in partial pressure of oxygen (PaO2) are associated with small increases in SpO2. In contrast, when the SpO2 level is ≤ 90%, a small decrease in PaO2 is associated with a large decrease in SpO2. Therefore, in otherwise healthy infants with bronchiolitis who have an SpO2 level > 90%, increasing PaO2 with supplemental oxygen will probably provide little benefit, particularly in the absence of respiratory distress and feeding difficulties. Emergency clinicians should consider maintaining a higher SpO2 in children with risk factors that shift the oxyhemoglobin dissociation curve, such as fever, acidosis, and some hemoglobinopathies.66

In addition, the patient’s work of breathing should be evaluated and considered in the decision of whether oxygen supplementation is needed. Patients with risk factors such as prematurity, bronchopulmonary dysplasia, or hemodynamically significant congenital heart disease warrant special attention due to the fact that they are at risk for developing a severe illness.67 These infants often have abnormal baseline oxygenation coupled with an inability to cope with the pulmonary inflammatory changes associated with bronchiolitis. This combination can result in hypoxia that is more severe and prolonged than that experienced by otherwise healthy infants, and clinicians should take this into account when developing strategies for using and weaning supplemental oxygen.

The AAP recommends that oxygen therapy be initiated judiciously when SpO2 levels fall consistently to or below 90%, and that the intensity of monitoring SpO2 levels be reduced as the infant improves.3 The 2014 AAP guidelines recommend (weak recommendation due to low-level evidence and reasoning) that “clinicians may choose not to administer supplemental oxygen if the oxyhemoglobin saturation exceeds 90% in infants and children with a diagnosis of bronchiolitis.”3 This is based on the limited knowledge regarding the poor accuracy of pulse oximetry, especially in the 76% to 90% range.52 Also, this weak recommendation is due to the very poor correlation between respiratory distress and oxygen saturation among infants with LRTIs.68 In addition, 2014 AAP guidelines recommend that clinicians may choose not to use continuous pulse oximetry for infants and children with a diagnosis of bronchiolitis (weak recommendation due to low-level evidence and reasoning).3

Fluid Administration

Infants with a respiratory rate > 60 breaths/min are at risk for compromised feeding, particularly if nasal secretions are copious. Infants with respiratory difficulty may develop nasal flaring, increased work of breathing, and prolonged expiratory wheezing, and are at increased risk of aspiration of food into the lungs.69 Children who have difficulty feeding safely because of respiratory distress should be given IV fluids and should receive nothing by mouth until the respiratory rate normalizes (based on patient age). The 2014 AAP guidelines suggest IV or nasogastric routes for fluid administration.3

In addition, due to the possibility of fluid retention related to production of antidiuretic hormone, which has been raised in patients with bronchiolitis, the use of isotonic fluids, in general, appears to be safer than hypotonic solutions. A 2014 meta-analysis showed that, among hospitalized children who required maintenance fluids, the use of hypotonic fluids was associated with significant hyponatremia compared to the use of isotonic fluids.70

Nasal Suction

Nasal suction should be used to clear secretions in infants with acute bronchiolitis if they exhibit respiratory distress or difficulties in feeding or sleeping. This is especially important in younger infants, who are obligatory nose breathers. Nonetheless, routine use of “deep” suctioning may not be beneficial and may be harmful.3

Bronchodilators

Albuterol/Salbutamol

The 2006 AAP Subcommittee on the Diagnosis and Management of Bronchiolitis recommended “a carefully monitored trial of adrenergic medication as an option” and that “inhaled bronchodilators should be continued only if there is a documented positive clinical response to the trial using an objective means of evaluation.”71 The use of bronchodilator agents continues to be controversial, with inconsistent results regarding their benefits in treating viral bronchiolitis. Numerous studies and systematic evidence-based reviews have attempted to summarize these results,72-75 but they have been confounded by the
variety of therapies used and outcome measures that range from effects of bronchodilators on oxygen saturation levels and clinical scores after 30 minutes and 60 minutes to effects on admission rates and length of hospital stay. In addition, the use of bronchodilators should be weighed against their potential adverse effects and costs, especially given that most patients will not benefit from such treatment.

In the revised 2014 AAP guidelines on the diagnosis, management, and prevention of bronchiolitis, clinicians were advised not to administer albuterol (or salbutamol) to infants and children with the diagnosis of bronchiolitis. This is a strong recommendation, which is supported by studies that show the risk outweighing the benefit. Two Cochrane reviews found that bronchodilators produce small, short-term improvements but do not affect the rate of hospitalization or the length of hospital stay. The 2014 AAP guidelines also state that “because clinical scores may vary from one observer to the next and do not correlate with more objective measures, clinical scores are not validated measures of the efficacy of bronchodilators.” Clinically significant tachycardia and tremors were the most often reported adverse effects that offset any clinical scores or improvements, per the guidelines.

Of note, children who had severe disease or respiratory failure were usually excluded from these studies and trials, and this evidence cannot be generalized to these situations. Therefore, many emergency clinicians continue to use a bronchodilator trial in patients with severe bronchiolitis or those with pending respiratory failure. Additionally, the above recommendations are intended for patients wheezing for the first time.

The 2017 Pediatric Emergency Research Networks (PERN) study suggests that there has been a decrease in the use of nonrecommended interventions. Nonetheless, more than 30% of infants hospitalized with bronchiolitis received supportive therapy that was not supported by evidence. Despite AAP guideline recommendations, there are still high rates of use of nonrecommended therapies and wide variation in the use of therapeutic interventions among hospitals worldwide, with rates of bronchodilator use ranging up to 90% reported in the period of 2007-2012.

**Epinephrine**

A meta-analysis indicated that there was a decrease in clinical symptoms after treatment with nebulized epinephrine as compared to either placebo or albuterol. A Cochrane review found no reduction in admission rates in the inhaled epinephrine treatment group, with some studies demonstrating short-term improvements in clinical scores, oxygen saturation levels, and respiratory rates.

The 2014 AAP guidelines strongly recommend emergency clinicians refrain from using epinephrine routinely—systemic or nebulized—as a treatment for children and infants with bronchiolitis. The AAP guidelines did state that there is need for more research to establish the use of epinephrine as a rescue agent for patients with severe bronchiolitis.

**Corticosteroids**

Although consistent evidence of the efficacy of corticosteroids in the treatment of bronchiolitis is lacking, it is estimated that up to 60% of infants hospitalized with bronchiolitis receive these medications. Some studies have suggested benefits with corticosteroid therapy, but a review of these studies, including sample size and methodology, demonstrated the inconclusive nature of the available evidence. A Cochrane review of 13 studies of the use of corticosteroids for bronchiolitis showed no significant differences in respiratory rates, oxygen saturation levels, initial admission rates, length of stay, subsequent visits, or readmission rates between corticosteroid and placebo treatment groups.

A placebo-controlled trial by Schuh et al evaluated 70 infants with moderate to severe bronchiolitis. The authors found significant decreases in respiratory scores after 4 hours of observation in infants who received oral dexamethasone 1 mg/kg and 0.6 mg/kg for an additional 5 days. The admission rate was significantly lower in the dexamethasone group compared to the placebo group (19% vs 44%, respectively). The study was limited by the small sample size and the larger proportion of positive family history of atopy in infants in the dexamethasone group (increasing the risk of having asthma) compared to those in the placebo group.

A landmark study conducted by the Bronchiolitis Study Group of the Pediatric Emergency Care Applied Research Network (PECARN) evaluated the use of corticosteroids in the treatment of bronchiolitis. Infants aged 2 to 12 months with first-time wheezing were enrolled at 20 medical center EDs from 2004 to 2006. The infants had “moderate” or “severe” symptoms as measured by a standard assessment rubric. Patients received 1 mg/kg of oral dexamethasone solution or the same volume of placebo fluid. Symptom scores and vital signs were assessed at entry, 1 hour, and 4 hours after receipt of the study medication or placebo. The local providers could decide on other ED care and laboratory testing at their discretion. Within 1 week after the ED visits, families were contacted to obtain information on side effects and rates of return visits for medical care. In all, 600 patients were randomly assigned to the treatment groups, and roughly equal numbers in the 2 arms had complete data. The patients in both groups received very similar treatment. There was no statistically significant difference in the percentages admitted to the hospital (39.7% of patients in the dexamethasone group were admitted vs 41% in the placebo group), even after adjustments for...
patient age, history of atopy, and positive RSV test results. The authors concluded that use of dexamethasone in the ED did not improve outcomes in first-time wheezers with bronchiolitis. This study did not address the question of corticosteroid effectiveness in infants with bronchiolitis and prior wheezing or in older children with bronchiolitis.94

Two studies that evaluated the use of inhaled corticosteroids in the treatment of bronchiolitis showed no benefit in the course of the acute disease.95,96 Unless there is a clear likelihood of benefit, high-dose inhaled corticosteroids should not be used in infants because of safety concerns such as impaired linear growth. Studies on the safety of inhaled corticosteroids for children aged < 24 months are scarce.

Supporting the previous study, the 2014 AAP guidelines strongly recommend refraining from treatment of bronchiolitis with corticosteroids in any setting.3 The recommendation is supported by a 2013 Cochrane review of 17 trials with 2596 participants. Overall, there was no reduction of bronchiolitis admissions or inpatient length of stay with corticosteroid administration.97

Combination Treatment With Epinephrine and Corticosteroids

Pediatric Emergency Research Canada conducted a double-blind, placebo-controlled multicenter trial at 8 Canadian pediatric EDs involving 800 infants aged 6 weeks to 12 months with bronchiolitis.98 Patients were randomly assigned to 1 of 4 study groups: (1) the epinephrine-dexamethasone group received 2 treatments of nebulized epinephrine (3 mL of epinephrine 1 mg/mL solution per treatment) and a total of 6 oral doses of dexamethasone (1 mg/kg in the ED and 0.6 mg/kg for an additional 5 days); (2) the epinephrine group received nebulized epinephrine and an oral placebo; (3) the dexamethasone group received nebulized placebo and oral dexamethasone; and (4) the placebo group received nebulized placebo and oral placebo. The primary outcome was hospital admission within 7 days after the ED visit. The epinephrine-dexamethasone group had a lower admission rate over 7 days than the placebo group (17.1% vs 26.4%, respectively). The study authors did not anticipate this potential interaction in the design, and after adjustment for multiple comparisons, the difference did not reach statistical significance. The combination of epinephrine and dexamethasone as a treatment for bronchiolitis must undergo further investigation before it can be implemented in routine practice. If the results are confirmed, the moderate effect (ie, 11 infants need to be treated for 1 not to be admitted) could represent a potentially important relative reduction in the number of hospitalizations for bronchiolitis.96

The synergy between adrenergic agents and corticosteroids has been well described in the asthma literature and has been observed in other small studies of bronchiolitis.91,98 Of note, the dose of dexamethasone used in the Pediatric Emergency Research Canada and the Schuh study (1 mg/kg for the first dose and 0.6 mg/kg for an additional 5 days) is much higher than the typical dose of dexamethasone used in other respiratory illnesses such as asthma and croup.92,96 A multicenter randomized controlled trial that assesses the clinical and cost-effectiveness of combined adrenaline and corticosteroids treatment for bronchiolitis is needed.

Anticholinergic Agents

Anticholinergic agents (eg, ipratropium bromide) are frequently given to children with wheezing because of their positive effects in the treatment of acute asthma exacerbation, but their role in the treatment of bronchiolitis is uncertain. A 2005 Cochrane review of the role of anticholinergic agents in the treatment of children aged < 2 years with wheezing identified 6 trials, only 2 of which involved patients with first-time wheezing.99 Compared with a beta-2-agonist alone, the combination of ipratropium bromide and a beta-2-agonist was not associated with a difference in treatment response, respiratory rate, or oxygen saturation improvement in the ED. There was no significant difference in the length of hospital stay between the ipratropium bromide and placebo groups or between patients receiving ipratropium bromide and a beta-2-agonist combined and those receiving a beta-2-agonist alone. At this time, use of anticholinergic agents—either alone or in combination with beta-adrenergic agents—is not justified for viral bronchiolitis in the ED.100-102 Therefore, the clinical trials demonstrating decreased admission rates for asthmatic patients with the use of ipratropium bromide should not be applied to patients with mild to moderate bronchiolitis.

Hypertonic Saline

Some studies have shown that hypertonic saline improves mucociliary clearance in pediatric patients with cystic fibrosis.103 Airway edema and mucus plugging are the predominant pathologic features in infants with acute viral bronchiolitis, and several studies have assessed the ability of nebulized hypertonic saline solution to reduce these pathologic effects and decrease airway obstruction.

A randomized double-blind placebo-controlled trial was conducted at a single pediatric ED to determine whether nebulized 3% hypertonic saline with epinephrine is more effective than nebulized 0.9% saline (normal saline) with epinephrine in the treatment of infants aged < 12 months with mild to moderate bronchiolitis. No improvements were noted in oxygen saturation levels and Respiratory Assessment Change scores assessed at baseline and at 120 minutes in the hypertonic saline group compared with the normal saline control group. In addition,
Clinical Pathway for Assessment and Management of Acute Bronchiolitis

Patient presents with suspected bronchiolitis

- Obtain history, physical examination, vital signs, pulse oximetry reading, and respiratory status
- Assess the risk for severe bronchiolitis and apnea (See Table 2, page 5)
- Assess the patient frequently (because of the variable disease course)
- Consider nasal suction prior to repeated examinations

Patient with mild bronchiolitis

- Manage without medication

Patient with severe bronchiolitis

- Severe respiratory distress and persistent hypoxia
  - Start nasal HFNC or CPAP plus heliox (Class III) or consider trial of bronchodilators (Class III)
- Improvement in respiratory status?
  - Respiratory status interferes with feeding
    - Start intravenous/nasogastric fluids
  - Respiratory status interferes with feeding
    - Start intravenous/nasogastric fluids

Patient with severe bronchiolitis

- Apnea/respiratory failure?
  - NO
    - Admit to pediatric critical care unit
  - YES
    - Intubate

Apnea/respiratory failure?

- NO
  - Admit to pediatric critical care unit
- YES
  - Intubate

Admission criteria:

- Risk for apnea
- Risk for severe bronchiolitis
- Respiratory distress, particularly if it interferes with feeding
- Hypoxia
- Decreased feeding
- Dehydration
- Unreliable caregiver to ensure patient care and appropriate follow-up

Abbreviations: HFNC, high-flow nasal cannula; nCPAP, nasal continuous positive airway pressure; SaO₂, oxygen saturation.

For Class of Evidence definitions, see page 11.
the rates of admission and return visits to the ED were similar between the groups. The authors of that study concluded that, in the emergency setting, treatment of acute bronchiolitis with hypertonic saline and epinephrine did not improve clinical outcomes any more than treatment with normal saline and epinephrine.104

The 2014 AAP guidelines recommend avoiding the use of hypertonic saline in the emergency setting, as it has no effect on admission rates (moderate evidence). However, it recommends using hypertonic saline in children hospitalized for bronchiolitis (weak evidence).3 This endorsement stems from the 2013 Cochrane review that analyzed 11 trials including over 1090 children with bronchiolitis in emergency room and inpatient settings. The results indicated that children treated with hypertonic saline while hospitalized had a reduction in length of stay when in the hospital for > 72 hours. Moreover, hospitalized children showed “incremental positive effect with each day posttreatment from day 1 to day 3.” Unfortunately, use in emergency settings does not show significant improvement, as it usually takes 24 hours to demonstrate clinical improvement.105

A 2017 Cochrane review assessed 28 trials involving 4195 infants who had acute bronchiolitis, of whom, 2222 infants received hypertonic saline. Hospitalized infants who were treated with nebulized hypertonic saline had statistically significant lower postinhalation clinical scores in the first 3 days of treatment and a shorter mean length of hospital stay compared to infants treated with nebulized normal saline. Of importance, nebulized hypertonic saline reduced the risk of hospitalization by 14% compared with nebulized normal saline among infants who were outpatients and those treated in the ED. Twenty-four trials presented safety data, with 13 trials not reporting any adverse events and 11 trials reporting at least one adverse event, most of which were mild and resolved spontaneously.106

The Australasian bronchiolitis guidelines state that, while there is weak evidence of reduced admission rates following the use of nebulized hypertonic saline, there is heterogeneity in the treatment regimens used and the data indicate that 1- to 2-dose regimens are ineffective. The guidelines did not support the routine use of nebulized hypertonic saline in the ED to reduce admissions.11

In a study published in 2017, no reduction in admission rates or length of stay was demonstrated when using hypertonic saline compared to normal saline. In fact, hypertonic saline was shown to have some minor adverse effects, such as worsening of cough. As such, hypertonic saline is not commonly recommended as a treatment modality due to inconsistent evidence substantiating its effectiveness.107

**Summary of Recommendations**
A summary of the treatment recommendations, supported by various guidelines, can be found in Table 3 and Table 4, page 12.

**Controversies and Cutting Edge**

**Bronchiolitis Treatments**

**High-Flow Nasal Cannula**

Over the past decade, HFNC has been widely used to support critically ill patients from premature neonates to adults. Infants with bronchiolitis can develop severe respiratory failure due to complex airway changes involving mucus plugs and increased airway resistance, alveolar atelectasis, muscle fatigue, and hypoxemia due to mismatch between ventilation and perfusion. HFNC oxygen and nCPAP have the potential to improve the work of breathing and oxygenation in patients with severe bronchiolitis. HFNC supports respiration through mucociliary clearance, reduced airway resistance, washout of the nasopharyngeal dead space, reduced metabolic work related to gas conditioning, and provision of low levels of positive airway pressure.108

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**Class of Evidence Definitions**

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

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

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

**Class II**
- Safe, acceptable
- Probably useful

**Level of Evidence:**
- Generally higher levels of evidence
- Nonrandomized or retrospective studies: historic, cohort, or case control studies
- Less robust randomized controlled trials
- 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

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

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Several pediatric intensive care unit (PICU) studies were conducted to evaluate the effectiveness of high-flow nasal cannula (HFNC) in patients with bronchiolitis. Two small retrospective studies of PICU patients who had moderate to severe bronchiolitis demonstrated that making HFNC available for clinical use was associated with a decreased overall need for intubation and mechanical ventilation.\cite{109,110} A larger study of PICU patients who had various etiologies of respiratory distress also showed reduced intubation rates after introduction of HFNC.\cite{111} A decline in intubation rate in the subgroup of infants with bronchiolitis from 37% to 7% after the introduction of HFNC was found in a large retrospective study conducted in Australia, while the national registry intubation rate remained at 26%.\cite{112}

A study by Wing et al of 848 children with acute respiratory insufficiency requiring PICU admission found overall intubation rates decreased from 15.8% to 8.1% with introduction of HFNC and establishment of a guideline for use. This included a decrease from 21% to 10% among children with bronchiolitis, with the vast majority being in the ED (from 10.5% to 2.2%).\cite{113} In a 2018 multicenter randomized controlled trial, 1472 infants aged < 12 months with bronchiolitis and a need for supplemental oxygen therapy were randomized to receive either HFNC (high-flow therapy group) or standard oxygen therapy (standard therapy group). The percentage of infants receiving escalation of care was 12% in the high-flow group as compared to 23% in the standard-therapy group. No significant differences were noted in the duration of hospital stay or the duration of oxygen therapy.\cite{114}

In a 2017 study, HFNC was found to be superior to standard low-flow oxygen delivery in preventing treatment failure in children who had bronchiolitis.\cite{115} Other studies demonstrated that HFNC was equivalent to more traditional modalities of noninvasive ventilation support (e.g., continuous or bilevel positive airway pressure [CPAP or BiPAP]).\cite{116,117}

One study compared HFNC with standard nasal cannula for less-ill patients who had bronchiolitis in the ED. HFNC was associated with faster improve-

<table>
<thead>
<tr>
<th>Table 3. 2014 AAP Clinical Practice Guideline Recommendations for the Diagnosis and Management of Bronchiolitis(^{3})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength of Evidence</td>
</tr>
<tr>
<td>Good</td>
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<td>Fair</td>
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<td>Poor</td>
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*See section on “Hypertonic Saline” on page 9 for studies conducted after the publication of the guideline.

<table>
<thead>
<tr>
<th>Table 4. Key Management Recommendations in Bronchiolitis Guidelines</th>
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</thead>
<tbody>
<tr>
<td>Guideline</td>
</tr>
<tr>
<td>AAP 2014(^{3})</td>
</tr>
<tr>
<td>SIGN 2006(^{6})</td>
</tr>
<tr>
<td>SNHS 2010(^{9})</td>
</tr>
<tr>
<td>CPS 2014(^{9})</td>
</tr>
<tr>
<td>NICE 2015(^{10})</td>
</tr>
<tr>
<td>Australasian 2019(^{11})</td>
</tr>
</tbody>
</table>

Abbreviations: AAP, American Academy of Pediatrics; CPS, Canadian Pediatric Society; NICE, National Institute for Health and Care Excellence; SIGN, Scottish Intercollegiate Guidelines Network; SNHS, Spanish National Health System.

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The HFNC flow rate should be based on patient weight and the perceived magnitude of respiratory support needed. (See Table 5.) There is no consensus on ideal HFNC flow. Some authors report using age-based protocols, such as 2 L/min for patients aged < 6 months, 4 L/min for patients aged 6 to 18 months, and 8 L/min for patients aged 18 to 24 months, or 8 to 12 L/min for infants and 20 to 30 L/min for children. Recent data supporting the effects of HFNC are dependent on weight, with other studies indicating weight-based dosing, such as 1 L/kg/min or 2 L/kg/min.

**Predictive Factors of Unresponsiveness to High-Flow Nasal Cannula Therapy in the Emergency Department**

Infants and children for whom HFNC failed (defined as a need for PICU admission or escalation to noninvasive or invasive ventilation) were younger and sicker upon presentation, with worse initial respiratory rate and no improvement in heart rate or respiratory rate, respiratory acidosis, and severity of illness scores.

Unresponsiveness to HFNC therapy in an ED is defined as an increase in the requirement of a higher level of respiratory support due to unchanged or increased respiratory rate compared to initial respiratory rate, incipient or progressive respiratory acidosis, and incipient hemodynamic instability. A 2018 retrospective study evaluated 154 infants (median age, 10 months). The diagnosis was acute bronchiolitis in 59 patients (38.3%), with the rest being bacterial pneumonia (41.6%), and atypical or viral pneumonia (20.1%). Twenty-five patients (16.2%) were in the unresponsive group, and the median time for escalating respiratory support was 7 hours. Low initial peripheral capillary oxygen saturation (SpO₂) and oxygen saturation/fraction of inspired oxygen (SpO₂/FiO₂; S/F) ratio, respiratory acidosis, and S/F ratio < 195 in the first hours of treatment were related to unresponsiveness to HFNC therapy.

There are some data that demonstrate a reduction in intubation and mechanical ventilation when HFNC is initiated in the ED. Large randomized clinical trials are needed to determine the exact role of HFNC in the treatment of pediatric patients in respiratory distress in the ED setting.

**Table 5. High-Flow Nasal Cannula Clinical Flow Ranges**

<table>
<thead>
<tr>
<th>Age</th>
<th>Weight Range (kg)</th>
<th>Starting Flow Rate (L/min)</th>
<th>Flow Range (L/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30 days</td>
<td>&lt; 4</td>
<td>4-5</td>
<td>4-8</td>
</tr>
<tr>
<td>1 month - 1 year</td>
<td>4-10</td>
<td>4-10</td>
<td>2-20</td>
</tr>
<tr>
<td>1-6 years</td>
<td>10-20</td>
<td>5-15</td>
<td>3-30</td>
</tr>
</tbody>
</table>

**Nasal Continuous Positive Airway Pressure**

By decreasing inspiratory muscle workload, preventing or relieving atelectasis, and preventing airway collapse, nCPAP could help in the treatment of bronchiolitis. Thia et al recruited children aged < 1 year with bronchiolitis and a capillary PCO₂ level > 6 kPa, and randomly assigned them to either nCPAP or standard treatment groups (IV fluids and supplemental oxygen by nasal prongs or facemask) and then crossed the patients over to the alternative treatment after 12 hours. The changes in PCO₂ levels were compared between the groups after 12 and 24 hours. After 12 hours, the PCO₂ level decreased by 0.92 kPa in children treated with nCPAP compared with an increase of 0.04 kPa in those receiving standard treatment. Patients who used nCPAP in the first half of the study experienced a significantly better reduction in PCO₂ level than those who used it during the second half. There were no differences in capillary pH, respiratory rate, pulse rate, and the need for invasive ventilatory support. Overall, nCPAP was well tolerated, with no complications identified. These study results suggest that nCPAP improves ventilation in children with bronchiolitis and hypercapnia when compared with standard treatment.

**Comparison of High-Flow Nasal Cannula and Continuous Positive Airway Pressure**

Both HFNC and CPAP are noninvasive modalities of respiratory support that may help infants with severe bronchiolitis by distending pressure and delivery of high concentrations of warmed and humidified oxygen. Their use has reduced the need for intubation. Recent studies have compared the efficacy of these modalities. In one study, children aged 1 to 24 months with respiratory distress in the ED setting were randomly treated with CPAP or HFNC until their clinical status, oxygen saturation, and arterial blood gas parameters resolved. The clinical response to CPAP was more efficient and rapid compared with HFNC. Patients on CPAP or HFNC had a better clinical course in terms of hospitalization, days of IV rehydration therapy, and days of drug administration compared with the control group. Another small study comparing treatment with CPAP to HFNC found no difference in hospital stay, length of treatment, complications, or transport to a PICU. However, CPAP was more effective than HFNC in decreasing respiratory rate and FiO₂. Large prospective randomized trials need to be conducted to further compare the efficacy of CPAP and HFNC as treatment for bronchiolitis.

**Heliox**

Heliox is a mixture of helium (a naturally inert gas with a low molecular weight) with 21% oxygen, producing a mixed gas one-third as dense as air. Its benefits in the treatment of obstructive airway diseases include reducing gaseous flow resistance.
and subsequently reducing respiratory effort and improving gaseous exchange and alveolar ventilation. Heliox also increases the elimination of carbon dioxide through its high diffusion coefficient.\textsuperscript{131}

A prospective randomized double-blind study assessed the effects of heliox on respiratory distress symptoms in young infants (aged < 3 months) with moderate to severe acute RSV bronchiolitis who were admitted to the PICU. The infants were blindly and randomly assigned to inhale either heliox or an air-oxygen mixture for 1 hour under an oxyhood. The mean respiratory distress score was significantly lower in the heliox group than in the air-oxygen group (3.05 vs 5.5, respectively). Patients in the heliox group also had a significant reduction in accessory muscle use and expiratory wheezing. In contrast, inspiratory breath sounds and incidence of cyanosis did not differ significantly between the groups. The respiratory distress score at baseline was higher in previously premature infants in the heliox group than in term infants in this group (5.8 vs 5.2, respectively; \( P < .05 \)), with comparable decreases in the scores at 1 hour. The authors of that study concluded that heliox breathing induced a rapid reduction in accessory muscle use and expiratory wheezing even in premature patients.\textsuperscript{131} Evidence from a 2015 Cochrane review of 7 trials involving 447 infants (only 1 ED trial of 69 patients) suggests that the addition of heliox therapy may significantly reduce a clinical score evaluating respiratory distress in the first hour after starting treatment, with no reduction in rates of intubation, ED discharge, or length of treatment. However, heliox could reduce the length of treatment for infants requiring CPAP for severe respiratory distress.\textsuperscript{132} Of note, patients who require high FiO\textsubscript{2} are not candidates for heliox, as the percentage of oxygen in the mixture may be insufficient.

**Heliox and Nasal Continuous Positive Airway Pressure**

The potential synergy between nCPAP and heliox is due to nCPAP-mediated promotion of heliox distribution within the obstructed airways by decreasing atelectasis and preventing airway collapse. The use of nCPAP may reduce the required FiO\textsubscript{2} and further augment the actual helium concentration delivered to the patient. Heliox actions reduce the risk of barotrauma from gas trapping, limiting the potentially detrimental effects of nCPAP.

A prospective interventional crossover study evaluated infants aged 1 month to 2 years who were admitted to the PICU for treatment of severe acute bronchiolitis that was unresponsive to therapy.\textsuperscript{133} Patients with a clinical score (ie, Modified Wood’s Clinical Asthma Score) \( > 5 \), an arterial oxygen saturation (SaO\textsubscript{2}) level < 92%, or transcutaneous CO\textsubscript{2} pressure \( > 50 \) mm Hg despite supportive therapy, and who used nebulized L-epinephrine and heliox therapy through a nonrebreathing reservoir face mask were included. Patients were randomly assigned to either 30 minutes of treatment with heliox with nCPAP or to air-oxygen with nCPAP, and measurements were taken at baseline and after 30 minutes of treatment. Although the clinical scores, transcutaneous CO\textsubscript{2} pressure, and SaO\textsubscript{2} levels improved with the use of both heliox with nCPAP and air-oxygen with nCPAP, better results were achieved with the use of heliox and nCPAP than with air-oxygen and nCPAP. In fact, the improvement in clinical scores was doubled in the heliox and nCPAP group compared to the air-oxygen and nCPAP group. Conversely, there was no difference in SaO\textsubscript{2} between the groups after 30 minutes of treatment. No patients required endotracheal intubation.\textsuperscript{133}

The beneficial effects of heliox and nCPAP demonstrated in these studies in infants with severe bronchiolitis are encouraging, especially given that improvements in the patients’ clinical condition and blood gas status were obtained in a safe and noninvasive manner. The treatment may provide time for other therapeutic agents to work or for the condition to resolve naturally and might help to avoid more aggressive interventions such as endotracheal intubation and mechanical ventilation. In addition, the response to heliox is rapid (ie, within the first hour) and is maintained during treatment, consistent with its mechanism of action. Therefore, nonresponders can be detected readily and other treatments can be initiated promptly. Multicenter research is needed to validate the results of these studies because of their limited number and small sizes. Other issues that need to be addressed are the optimal timing of intervention, the ideal initial and maintenance parameters, and the duration of treatment.

**Leukotriene Receptor Antagonists**

Another therapy currently being explored as treatment for bronchiolitis is the leukotriene receptor antagonist, montelukast. Benefits in time to resolution of symptoms with this therapy are not apparent.\textsuperscript{134-136}

**Bronchiolitis and Vitamin D Deficiency**

Recent reports have related the increased incidence of severe bronchiolitis to the increased incidence of vitamin D deficiency.\textsuperscript{137} Low levels of vitamin D are quite common among newborns born in the United States\textsuperscript{138,139} and these low levels have been associated with an increased incidence of pneumonia and LRTI requiring hospitalization.\textsuperscript{140-142}

The pathophysiology of these observations may relate to the role of vitamin D in the activity of the immune system.\textsuperscript{143} Camargo et al recently found that lower maternal intake of vitamin D during pregnancy had a statistically significant, independent association with increased risk of recurrent
childhood wheeze, a finding that was replicated in 5-year-old Scottish children. In addition, Camargo et al confirmed this finding in a separate birth cohort from New Zealand, in whom low vitamin D levels in cord blood were associated with increased risks of respiratory infections at 3 months and wheezing in early childhood. In a 2015 study, among 145 infants aged < 1 year and hospitalized with their first episode of RSV bronchiolitis, vitamin D status at the time of bronchiolitis was not associated with indicators of acute bronchiolitis severity. Indicators of bronchiolitis severity included duration of hospitalization, lowest oxygen saturation measured during hospitalization, and bronchiolitis severity score. Further research is needed to investigate the relationship between bronchiolitis and vitamin D deficiency and has the potential to help prevent this common illness.

**Bronchiolitis and Asthma**

The relationship between bronchiolitis and the development of asthma has been studied for years. It has been estimated that 50% of children with bronchiolitis have recurrent wheezing or asthma during the following 2 decades of life. This is particularly true in rhinovirus bronchiolitis. In a study that compared the development of asthma after infections with RSV or rhinovirus, 10% of patients in the RSV group had asthma compared to 60% of patients in the rhinovirus group. The results from a small trial of prednisolone use for 3 days versus placebo in children hospitalized with their first or second episode of wheezing due to rhinovirus bronchiolitis are of particular interest. This trial demonstrated that children who had rhinovirus bronchiolitis and received prednisolone had fewer relapses during a 2-month period after hospitalization and less recurrent wheezing at 1 year. Further research should focus on clarifying the potential benefits of identifying and treating rhinovirus bronchiolitis in order to prevent the development of asthma.

Infants and toddlers who have presented with bronchiolitis have been known to have wheezing, and this is not uncommon. A frequent question from parents to physicians is, “does my child have or will my child have asthma?” Unfortunately, there is no straightforward answer; however, literature shows a correlation between early childhood bronchiolitis and asthma development. A prospective cohort study following young children hospitalized with severe RSV bronchiolitis showed approximately 50% of the children developed asthma by the age of 7, with the most severe cases of bronchiolitis having the most risk of asthma. Formal asthma testing typically relies on spirometer testing, which most children could not meaningfully participate in until approximately age 5 years. Referral to pulmonology for recurrent wheezing evaluation may be worthwhile.

**Disposition**

Most children with bronchiolitis have mild disease and are discharged home. Some patients with bronchiolitis will have a severe course manifested by dehydration, respiratory distress, respiratory failure, apnea, or death. The most challenging task for emergency clinicians is to determine the appropriate disposition for a young infant, as the disease course is extremely variable.

Infants with bronchiolitis are frequently hospitalized because of respiratory distress, hypoxia, or dehydration due to their inability to take fluids secondary to the increased work of breathing. (See Table 6.) In addition, concerns about apnea will affect the decision to admit the patient.

Arbitrary thresholds for oxygen therapy may also influence the decision to admit patients with bronchiolitis. A survey of emergency physicians demonstrated that a reduction in the patient’s pulse oximetry level from 94% to 92% in a clinical vignette significantly increased the likelihood of the physicians to recommend hospitalization. The study stated that most emergency physicians are not comfortable discharging patients home with an oxygen saturation of ≤ 92%.

Infants with SpO2 levels ≤ 90% require close observation and hospitalization. Decisions regarding hospitalization of infants with SpO2 levels between 90% and 92% should be supported by a detailed clinical assessment (eg, the presence of tachypnea, increase in the work of breathing, and the ability to take fluids, etc), consideration of the phase of the illness, and should take social factors into account. A British study revealed that the mean lag time for SpO2 levels to normalize was 66 hours after all other problems had resolved. Of note, as a result of continuous pulse oximetry monitoring, a substantial proportion of infants remain in the hospital for administration of oxygen after other abnormalities have improved. Novel approaches such as the use of home oxygen therapy have been studied in some populations, and further research on the use of home oxygen in treating bronchiolitis is needed.

**Table 6. Criteria for Hospitalization**

Patients with bronchiolitis should be considered for admission if they have any of the following:

- Risk for apnea (See Table 2, page 5.)
- Risk for severe bronchiolitis (See Table 2, page 5.)
- Respiratory distress, particularly if it interferes with feeding
- Hypoxia (oxygen saturation ≤ 90%)
- Decreased feeding and/or dehydration
- An unreliable caregiver (ie, unable to ensure patient care and appropriate 24-hour follow-up)

All patients with severe bronchiolitis should be admitted.
A study published in 2016 compared the difference in the proportion of unscheduled medical visits within 72 hours of ED discharge in infants with bronchiolitis who have oxygen desaturations < 90% for at least 1 minute during home oximetry monitoring versus those without desaturations. Children with and without desaturations had comparable rates of return for care, with no difference in unscheduled return medical visits or delayed hospitalizations. The authors suggested that stable infants with mild to moderate bronchiolitis could be observed and have their pulse oximetry levels spot-checked in the ED setting prior to discharge. The authors stated that the results of this study do not apply to inpatient settings or infants with chronic desaturations due to chronic respiratory conditions.

1. “The 4-month-old patient was wheezing, so we tested him for RSV.”
   The diagnosis of bronchiolitis is based on the history and physical examination. Viral testing will not change the ED course. Consider obtaining RSV testing if the patient is being admitted and has been receiving monthly palivizumab as prophylaxis. If a breakthrough RSV infection is present (based on antigen detection or another assay), monthly prophylaxis should be discontinued due to the very low likelihood of another RSV infection in the same year.

2. “I always admit first-time wheezing patients with bronchiolitis if they do not clear in the ED.”
   One of the main reasons to admit patients with bronchiolitis is the concern regarding the development of apnea. Risk factors for apnea include young age (< 6-12 weeks old), prematurity, a history of apnea of prematurity, presentation with apnea, or apnea witnessed by a parent or healthcare provider. In addition, patients with bronchiolitis may be admitted because of respiratory distress, hypoxia, or dehydration related to the inability to take fluids secondary to increased work of breathing. Wheezing alone is not a criterion for admission unless it is associated with other risk factors for severe disease or apnea. Social factors such as parental comfort and reliability in ensuring appropriate care and follow-up should be taken into consideration when disposition decisions are made in the ED.

3. “The infant was wheezing, so we sent her home on steroids.”
   In contrast to the demonstrated effectiveness of dexamethasone in treating asthma and croup, no conclusive evidence has been shown to date that the use of systemic dexamethasone improves outcomes in first-time wheezing patients with bronchiolitis. In addition, because of safety concerns with the use of high-dose inhaled corticosteroids in infants, these medications should be avoided unless there is a clear likelihood of benefit.

4. “The neonate was wheezing, so I diagnosed her with bronchiolitis.”
   Other life-threatening causes of wheezing should be considered. Clues from the history and physical examination such as sweating and exertion with feeding, heart murmur, and hepatomegaly should be elicited to rule out congenital heart failure and “cardiac wheezing.” This determination is important before starting a trial of nebulized adrenergic treatment.

5. “The 2-month-old born at 30 weeks’ gestation with chronic lung disease had mild wheezing and a respiration rate of 60 breaths/min. Pulse ox reading was 92% on room air after a nebulized adrenergic treatment, so I sent her home with albuterol and frequent bulb suctioning.”
   Bronchiolitis presentation is variable, and tachypnea and increased work of breathing can precede wheezing. This patient has 3 risk factors for severe disease, including young age, prematurity, and hypoxia. In addition, she has a risk factor for apnea (ie, < 48 months post conception). Close observation is warranted.
The admission of well-appearing children with bronchiolitis who are at high risk for unscheduled visits is debatable, as the goals of admission are primarily close observation and supportive therapy. Close follow-up with the primary care provider and strict anticipatory guidance instructions could eliminate the need for hospitalization. It is important for emergency clinicians to contact the primary care provider from the ED to discuss follow-up and any clinical concerns.

**Summary**

Acute bronchiolitis is a clinical diagnosis; diagnostic laboratory and radiographic tests play a limited role in typical cases. Emergency clinicians should assess for high-risk factors for severe bronchiolitis manifest by respiratory distress, increased work of breathing, and decreased feeding and dehydration, hypoxia, respiratory failure, and apnea. These factors include age < 6 to 12 weeks, prematurity, and underlying comorbidities such as chronic lung disease, cardiopulmonary disease, and immunodeficiency.

Pulse oximetry drives the use of healthcare resources. Supplemental oxygen is indicated if the patient’s SpO\textsubscript{2} level is consistently ≤ 90% or at higher pulse oximetry readings if the patient is in respiratory distress or has an underlying disease that causes abnormal baseline oxygenation. Numerous large trials have demonstrated the lack of efficacy of bronchodilators and corticosteroids in the treatment of acute first-time bronchiolitis. Other recent studies suggest the potential future role of combination therapies and HFNC.

Frequent evaluations of patient clinical status including respiratory rate, work of breathing, oxygenation, and pulse oximetry readings can facilitate early intervention and help prevent hospitalization. A child’s clinical status must be reevaluated every 4 to 6 hours, and the frequency of evaluations should be adjusted based on the child’s response to therapy and clinical stability.

**Risk Management Pitfalls in the Management of Pediatric Bronchiolitis**

(Continued from page 16)

6. **“I ordered a radiograph because the wheezing patient had a fever.”**
   In the ED, radiographs should not be obtained routinely for diagnosis of bronchiolitis because no evidence supports the practice. Radiographs may be useful in cases of severe disease that require further evaluation or if another diagnosis such as foreign body aspiration, pneumonia, or congenital heart failure is suspected on the basis of the history and physical examination findings.

7. **“The mother stated that her 1-month-old baby had a runny nose and cough for 2 days. The nurse called because the baby turned blue for a brief period. Upon reassessment, his breathing rate was 60 breaths/min, and his pulse oximetry reading was 96% on room air, so I sent him home.”**
   Young age (< 1 month old) and witnessed apnea by a healthcare provider are major risk factors for developing another apneic episode or persistent apnea. Admission of this neonate to a monitored bed (with apnea monitor) is indicated.

8. **“The infant with bronchiolitis failed nasal cannula therapy at 2 L/min. I didn’t know whether I should transfer him to the ICU and start nCPAP or consider endotracheal intubation.”**
   For children who fail low-flow nasal cannula therapy at 2 L/min, HFNC therapy can be trialed. Studies have shown infants and young children who failed low-flow nasal cannula have decreased ICU admissions when rescued by HFNC therapy.

9. **“The infant was stable but having trouble clearing mucus in the ED. He already had nasal suctioning, so we trialed nebulized hypertonic saline for symptomatic relief and sent him home.”**
   Nebulized hypertonic saline has shown benefit in some studies in reducing hospitalization length of stay when used for > 3 days; however, it has not been shown to have much benefit when used in the ED setting or in brief time frames. The AAP moderately recommends not giving hypertonic saline in the ED.

10. **“The ‘happy wheezer’s’ pulse oximetry reading was 92% on room air, so I immediately administered supplemental oxygen.”**
    In a wheezing patient who has no respiratory distress but has low SpO\textsubscript{2}, the first priority is to ensure that pulse oximetry probes are placed appropriately, particularly in the active infant/child. Poorly placed probes and motion artifacts will lead to inaccurate measurements and false alarms. Before instituting oxygen therapy, the initial reading should be verified by repositioning the probe and repeating the measurement. The infant’s nose should also be suctioned. If the SpO\textsubscript{2} level remains ≤ 90%, oxygen should be administered. The infant’s clinical work of breathing should also be assessed and may be a factor in the decision to use oxygen supplementation.
and ability to take fluid orally after any intervention are very important to determine safe patient disposition. Emergency clinicians can help decrease the financial burden of this condition by using history and physical examination findings and strict criteria for diagnostic testing to assess and manage bronchiolitis in young children.

Case Conclusions

You quickly determined that your patient had severe bronchiolitis, and you knew that aggressive management was required. You placed the patient on pulse oximetry because the infant had wheezed previously, and started a trial of a nebulized bronchodilator with oxygen while closely monitoring his clinical response to treatment. Your patient’s respiratory rate was still in the 70s, with minimal decreases in the work of breathing. His pulse oximetry level was 87% on room air, so you administered supplemental oxygen via HFNC. The patient started to cry without tears, and you noticed his dry mucous membranes, so you administered IV fluids. His respiratory rate was 55 breaths/min with no retractions, and he was able to take his bottle for only a brief period even after the nurse suctioned his nasal secretions. His SpO₂ level remained at 90% on room air. You decided to admit the patient because his tachypnea was leading to compromised oral intake and because of his persistent hypoxia, and you kept him on the HFNC in the meantime.

The physical examination and history for the 6-week-old boy led you to conclude that he likely had bronchiolitis. It was apparent to you that the child was in the high-risk category for multiple reasons, including prematurity, age < 6 weeks, and poor feeding. Because the patient had poor feeding despite nasal suctioning, you administered IV fluids. After some observation, an oral challenge was performed, and the infant failed. You knew that each course of bronchiolitis is variable, but that the typical disease process worsens around day 3 or 4. The infant remained tachypneic with poor oral intake. You decided to admit the patient for IV hydration and observation. You tested the patient for influenza, which was negative. Contact and droplet isolation precautions were observed.

Time- and Cost-Effective Strategies

- Avoid routine radiographs and laboratory studies in the diagnosis of acute bronchiolitis to decrease costs, radiation exposure, and blood testing in infants and young children who present to the ED with the typical signs and symptoms of bronchiolitis. Radiographs should be obtained only if the disease severity requires it or if there is suspicion of a different etiology for the wheezing or respiratory distress.
- Avoid routine use of bronchodilators in the management of bronchiolitis, especially when the disease is mild to moderate (ie, in well-hydrated “happy wheezers” with no hypoxia or respiratory distress). These medications provide inconsistent benefits, and their use should be weighed against potential side effects and costs.

References

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

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


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1. Which of the following symptoms is NOT consistent with the clinical definition of bronchiolitis?
   a. Tachypnea
   b. Wheezing
   c. Stridor
   d. Use of accessory muscles

2. Which of the following is responsible for bronchiolitis recovery lasting > 12 days?
   a. Smooth muscle constriction
   b. Normal regeneration of ciliated epithelial cells
   c. Increase in lung compliance creating secondary air trapping
   d. Defective macrophage response

3. Which of the following disorders should be considered in the differential diagnosis of bronchiolitis?
   a. Pneumonia
   b. Congestive heart failure
   c. Asthma
   d. All of the above

4. Which of the following historical findings is NOT a risk factor for severe bronchiolitis?
   a. History of wheezing
   b. Age < 12 weeks
   c. Prematurity (< 34-35 weeks’ gestation)
   d. Significant congenital heart disease and an immune deficiency

5. Which of the following physical examination findings is NOT a risk factor for severe bronchiolitis?
   a. Oxygen saturation level ≤ 90% on room air
   b. Severe nasal congestion
   c. Respiratory rate > 70 breaths/min or a higher than normal rate for the patient’s age
   d. Increased work of breathing (ie, moderate to severe retractions and/or accessory muscle use)

6. Which of the following findings is NOT considered a risk factor for apnea with bronchiolitis?
   a. Full-term birth and < 1 month of age
   b. Apnea witnessed by a caregiver
   c. High fever
   d. Preterm birth (< 36 weeks’ gestation) and < 2 months post birth

7. In a well-appearing young infant with high fever and bronchiolitis, which of the following is the most common serious bacterial infection that a patient should be evaluated for?
   a. Pneumonia
   b. Urinary tract infection
   c. Bacteremia
   d. Meningitis
8. An infant presents to the ED with severe bronchiolitis in severe respiratory distress and remains persistently hypoxic on room air, at 87% on pulse oximetry. What is the initial appropriate course of action?
   a. Intubate the patient.
   b. Start high-flow nasal cannula (HFNC) oxygen therapy or nasal continuous positive airway pressure.
   c. Admit the patient to the pediatric intensive care unit.
   d. Admit the patient to the general pediatric floor for observation.

9. Which of the following statements describes how HFNC improves ventilation in patients with bronchiolitis?
   a. Increases airway resistance
   b. Decreases mucociliary clearance
   c. Decreases inspiratory muscle workload
   d. Increases oxygenation

10. Of the children with bronchiolitis listed below, which of the following does NOT meet criteria for hospitalization?
    a. A 6-month-old with a pulse oximetry of 89%
    b. An 11-month-old with decreased oral intake and dry mucous membranes
    c. An 8-month-old who does not have a primary care provider and has a teenage mother with no transportation
    d. A 5-month-old with a pulse oximetry of 93% and a pediatrician appointment in 1 to 2 days

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

Goals: Upon completion of this activity, you should be able to: (1) demonstrate medical decision-making based on the strongest clinical evidence; (2) cost-effectively diagnose and treat the most critical ED presentations; and (3) describe the most common medicolegal pitfalls for each topic covered.

CME Objectives: Upon completion of this activity, you should be able to: (1) diagnose and assess bronchiolitis severity based on the patient’s history and physical examination; (2) recognize risk factors associated with apnea due to bronchiolitis; (3) discuss the controversies surrounding the use of bronchodilators and corticosteroids in patients with bronchiolitis; and (4) identify criteria for hospitalization of patients with bronchiolitis.

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