

## Acute lower respiratory disease in children

Rebecca Paris, Oliver Ross\*, and Laura Molyneux

\*Correspondence Email: oliver.ross1@btinternet.com

### INTRODUCTION

Pneumonia is the leading cause of death in children worldwide. Vulnerability is highest in the first 28 days of life, remaining a huge burden in the subsequent five years. In 2010 it was estimated that throughout the world 21,000 children under the age of five died every day, with a total of 7.6 million deaths each year.<sup>1</sup> Of these 1.4 million deaths (18%) were attributable to pneumonia, which is more than those caused by AIDS, malaria and tuberculosis combined.<sup>1,2</sup>

The vast majority of these childhood deaths occur in the developing world, particularly in Africa and South East Asia. The risk of a child dying under the age of five in a low-income country is 18 times greater than in a high-income country.<sup>1</sup> The highest under-5 mortality rates are seen in the poor rural communities with low levels of education.<sup>1,3-5</sup> Poverty contributes to increasing susceptibility through risk factors such as malnutrition, inadequate sanitation, and reduced access to health care services.<sup>1,3,6</sup> Inhalation of particulate matter from indoor air pollution caused by the use of biomass fuels for heating or cooking is responsible for almost half of deaths due to acute lower respiratory tract infections.<sup>2,7</sup>

### DEFINITIONS

Acute lower respiratory disease in children consists of asthma (acute severe or life-threatening asthma) and Acute Lower Respiratory Infections (ALRI), which includes pneumonia and bronchiolitis. All are acute, serious and potentially life threatening.

Pneumonia is an acute lower respiratory tract infection that presents with symptoms of cough, fever, and difficulty breathing.

Asthma is a condition of hyper-reactive, inflamed and narrowed airways resulting in difficulty breathing, wheeze, cough and chest tightness. Although a chronic condition, patients often present with acute exacerbations related to infective or non-infective triggers (physical exertion, allergens, irritants or cold weather).

Bronchiolitis is an acute, communicable condition mainly affecting infants between 3-6 months of age.

Starting as an upper respiratory tract infection, it is caused by viral infections, which then trigger lower respiratory symptoms of bronchospasm, wheeze, cough and respiratory distress.<sup>8</sup>

### PNEUMONIA

Pneumonia is most commonly caused by the bacteria *Streptococcus pneumoniae* (Spn) or *Haemophilus influenzae* (HiB). Other significant bacteria include *Staphylococcus aureus* and *Klebsiella pneumoniae*. Viral causes of pneumonia include Respiratory Syncytial Virus (RSV), parainfluenza virus and adenovirus. Fungal infections such as pneumocystis jiroveci are important to consider in the child with AIDS.<sup>2,5</sup> Increasing immunisation coverage against Spn and HiB is expected to change the aetiology of pneumonia. The Pneumonia Etiology Research for Child Health (PERCH) study is a large multinational study investigating the aetiology of pneumonia in children.<sup>9</sup>

Transmission of pathogens between individuals usually occurs via droplets, which are aerosolised through coughing and sneezing. Neonates are also at risk of blood borne infection at or shortly after birth.<sup>2,5</sup>

Risk factors for childhood ALRI are shown in Box 1. It is estimated that more than 20 million children suffer severe malnutrition, which compromises their defence against infection and increases their risk of dying from pneumonia. Immunity can also be weakened by concurrent illnesses such as HIV or measles. Non-exclusively breast fed infants are 15 times more likely to die from pneumonia, and suffer more frequent and severe infections than exclusively breastfed children.<sup>2,4</sup>

Approximately one million children could be saved through effective prevention and treatment of pneumonia every year.<sup>2</sup> The Global Action Plan for the Prevention and Control of Pneumonia presents a framework to reduce pneumonia morbidity and mortality through three facets:<sup>7</sup>

1. Protection - strategies include the provision of a healthy living environment to enhance natural defences.

### SUMMARY

Pneumonia continues to be the leading cause of death in children under 5, worldwide

Poverty contributes notably - the risk of a child dying under the age of five is 18 times greater in a low income country

Assessment and initial management follows the ABC approach, as for any acutely ill child

Standardised and prompt treatment improves outcomes

Supplementary oxygen saves extra lives.

### Rebecca Paris

Specialist Registrar  
in Anaesthesia  
Worcester Royal Hospital

### Laura Molyneux

Specialist Registrar  
in Anaesthesia  
Leeds General Infirmary

### Oliver Ross

Consultant Paediatric  
Anaesthetist  
Southampton  
University Hospital

2. Prevention - includes using immunisation against *Haemophilus influenzae* B, *Streptococcus pneumoniae*, measles and pertussis. Children with HIV or diarrhoea are at even greater risk of pneumonia, and infected or exposed children should receive daily cotrimoxazole prophylaxis.<sup>2,7</sup>

3. Treatment - for children with pneumonia, the mainstay of reducing mortality is appropriate treatment, either in the community, health centre or hospital. Evidence shows mortality can be reduced through:

- Standardised guidelines for diagnosis and treatment
- Early recognition and treatment with antibiotics.

The majority of cases of pneumonia in developing countries are bacterial in origin, but it is not possible to differentiate pathogens by clinical assessment.<sup>5</sup> Less than 30% of children with pneumonia receive the appropriate antibiotics.<sup>2</sup>

## ASTHMA

Over the past four decades the global prevalence, morbidity and mortality of asthma has risen sharply, particularly in children. While most of the 180,000 annual deaths from asthma are in patients over the age of 45 years, there has been a marked increase in hospitalisation in very young children. Prevalence of asthma is already high in

### Box 1. Risk factors for Childhood Acute Lower Respiratory Infection (ALRI)<sup>3,10-12</sup>

#### Definite Risk Factors for ALRI

- Malnutrition
- Low birth weight
- Non-exclusive breast feeding for first 6 months
- Lack of measles immunisations (within first 12 months)
- Indoor air pollution
- Crowded living

#### Likely Risk Factors for ALRI

- Parental smoking
- Zinc deficiency
- Maternal experience
- Concomitant diseases (diarrhoea, cardiac disease, asthma)

#### Possible Risk Factors for ALRI

- Mother's education
- Day-care attendance
- Rainfall (humidity)
- High altitude (cold air)
- Vitamin A deficiency
- Birth order
- Outdoor air pollution

high-income countries, reflecting increasing atopic sensitization. Prevalence is increasing in developing countries, possibly as a result of urbanization.<sup>13</sup>

Prevention of acute life threatening exacerbations depends on effective management of chronic disease. As with many diseases, this is hampered by poverty, poor education and limited access to health care.

## BRONCHIOLITIS

Bronchiolitis predominantly affects infants under six months old. It is a leading cause of ALRI and a major contributor to acute respiratory distress, hospitalisation and PICU admission<sup>14,15</sup> The most common pathogen is RSV and it is estimated that almost 199,900 children under the age of 5 died in 2005 as a result of RSV-associated ALRI. As with pneumonia, 99% of these deaths occurred in developing countries.<sup>14</sup> Other infective agents include human meta-pneumovirus (HMPV), influenza, para-influenza, adenovirus, rhinovirus, and less commonly *Mycoplasma pneumoniae*.

Risk factors for bronchiolitis are shown in Box 2.

Morbidity and mortality may be reduced by ensuring a healthy living environment and addressing risk factors in a similar manner to those for pneumonia. Vaccination for RSV is only recommended in high-risk groups (e.g. children with significant cardiac disease), and has been shown to reduce the length of illness, reduce hospital stay and intensive care admissions.<sup>15,16</sup>

## PRESENTATION AND DIFFERENTIAL DIAGNOSIS

The common presenting symptoms and signs of acute lower respiratory tract disease are cough, difficulty breathing and wheeze. The differential diagnoses are summarised in Table 1. Children normally have a higher respiratory rate than adults; normal cardio-respiratory ranges are shown in Table 2. As a rule of thumb, a respiratory rate of more than 50 breaths per minute in a child aged between 2 and 12 months, or more than 40 breaths per minute in a child aged 1-5 years is considered rapid (Table 3). Upper airway conditions are described in detail in another article of this *Update* (page 168).

## DIAGNOSIS, TRIAGE, AND MANAGEMENT

Assessment and triage of the seriously ill child are described in detail in 'Recognising the seriously ill child' in this edition of *Update* (page 224). Undertake an ABC assessment and categorise children according to the Emergency Triage Assessment and Treatment (ETAT) need for treatment<sup>28</sup>: Emergency, Priority or Non-urgent. Emergency cases require immediate attention; priority cases require assessment and rapid attention; non-urgent cases can wait their turn in a queue.

Use a step-wise ABC approach for all critically ill children. You must monitor and record vital signs regularly (oxygen saturation, respiratory rate, heart rate, conscious level and temperature). Any deterioration should prompt full reassessment of the child:

- Re-evaluate the diagnosis
- Look for complications of the disease

## Box 2. Risk factors for developing bronchiolitis<sup>14,15</sup>

- Prematurity
  - Male gender
  - Age <3 months
  - Indoor air pollution (smoking/ biomass fuels)
  - Non-breast feeding
  - Poverty
  - Respiratory disease (chronic lung disease of prematurity, cystic fibrosis)
  - Congenital heart disease with pulmonary hypertension
  - Immunodeficiency
  - Neurodevelopmental delay
  - Upper airway obstruction
- Ask for senior support
  - Consider the need to transfer the child to intensive care facilities.

## Pneumonia

The WHO recommends using clinical features of a recent onset cough and rapid breathing to diagnose pneumonia.<sup>5,28</sup> Normal and abnormal cardiorespiratory values are shown in Tables 2 and 3. Consider other respiratory illnesses than pneumonia if the child has a cough without rapid breathing. Remember, it is not possible to differentiate between viral or bacterial pneumonia clinically as the symptoms are so similar. Some symptoms, such as wheezing do tend to occur more commonly in viral pneumonia, but do not rely on this to direct treatment.

When a child presents with symptoms of pneumonia, triage by the severity of their disease (See Table 4). Seek specific signs and symptoms, in particular

- The 'danger signs' (cyanosis, stridor, somnolence, lethargy or difficulty feeding)
- Lower chest wall in-drawing
- Rapid respiratory rate.

In normal respiration the whole chest expands with inspiration. In severe disease the lower chest wall may be sucked in during inspiration (lower chest in-drawing). In combination with rapid breathing and cough this represents severe clinical pneumonia. Other signs of severe difficulty in breathing are grunting with each breath, nasal flaring and tracheal tug. Children with very severe pneumonia will have additional symptoms and signs such as cyanosis, stridor, the inability to feed or drink, loss of consciousness, hypothermia or convulsions. They need urgent transfer to hospital.

Pulse oximetry correlates well with arterial PaO<sub>2</sub> in adults and is recommended by WHO for detecting hypoxia in children with acute respiratory disease and for guiding oxygen therapy.<sup>19</sup> Target oxygen saturations are shown in Table 2. Where a pulse oximeter is not available, clinical signs can give useful clues to the presence of hypoxia:

- Central cyanosis
- Nasal flaring
- Grunting
- Altered mental state (drowsiness or lethargy)
- Inability to feed due to respiratory distress.

Be aware that no single sign can accurately identify hypoxia, so you should take signs together in context of the overall clinical condition of the child.<sup>31-33</sup> For example, the blue discolouration of lips or nail beds in central cyanosis can be difficult to identify. There is inter-observer disagreement and assessment is further complicated by the presence of severe anaemia (Hb<7g.dl<sup>-1</sup>) or in dark skinned children. Central cyanosis is a highly specific sign but with low sensitivity.<sup>32</sup> In a critically ill child, severe lower chest wall in-drawing, breathing rate of more than 70min<sup>-1</sup> or head bobbing may be more sensitive signs signaling the need for supplementary oxygen.<sup>19</sup>

Immediate treatment is outlined in Table 4. Many investigations to direct management (chest X-rays, blood tests, sputum tests) may be unavailable in the low-resource setting thus diagnosis and management is based on clinical symptoms and signs.<sup>4</sup> All children with severe or very severe pneumonia and infants aged two months or younger require admission to hospital.<sup>2</sup>

The current recommendation is to administer IV antibiotics for at least three days. As the child recovers, switch to oral antibiotics (amoxicillin or ampicillin), and ensure that the child completes a total of at least five days. Reassess on a regular basis. Clinical deterioration or failure to improve by 48 hours should prompt a change in antibiotics (to chloramphenicol).<sup>18</sup> Parenteral ampicillin plus gentamicin is preferable to chloramphenicol in treating severe pneumonia in children between one month and five years of age in a low-resource setting.<sup>34</sup>

## Complications of pneumonia

Hypoxaemia is the most serious complication of pneumonia.<sup>35</sup> It indicates severe disease and has been associated with four times increase in mortality.<sup>31,36</sup> Most children who require oxygen will have very severe pneumonia, but hypoxia may also be present in children with less severe disease.

Oxygen is an expensive resource. Oxygen concentrators require a reliable supply of electricity and many rural health facilities may need to use cylinder supply. Cylinders are logistically challenging to transport to remote areas so that shortages occur frequently. Monitoring oxygen saturation and providing oxygen to children with severe pneumonia reduces the risk of death by 35%. This is in part due to improved detection of hypoxia and regular reassessment of treatment.<sup>35</sup> Neonates are vulnerable to the toxic effects of hyperoxia,

**Table 1.** Differential diagnosis for children presenting with acute respiratory symptoms<sup>2,5,15,17-25</sup>

	<b>Presenting Feature</b>
<b>Pneumonia</b>	<ul style="list-style-type: none"> <li>• Most common in 0-5-year-olds</li> <li>• Cough for less than 2 weeks</li> <li>• Rapid breathing rate or difficulty breathing</li> <li>• Fever or chills</li> <li>• Wheeze</li> <li>• Hypoxia (low SpO<sub>2</sub> or clinical signs - see text)</li> <li>• Loss of appetite or unable to feed due to respiratory distress</li> </ul>
<b>Bronchiolitis</b>	<ul style="list-style-type: none"> <li>• Age 3-6 months (less than 2 years)</li> <li>• 2-3 day coryzal phase with nasal discharge</li> <li>• Fast or difficult breathing</li> <li>• Harsh cough</li> <li>• Irritability or poor feeding</li> <li>• Wheeze</li> <li>• Fever &lt;39°C</li> <li>• Apnoeas (especially in preterm infants)</li> <li>• Bilateral crepitations</li> <li>• Clinical signs of air trapping</li> </ul>
<b>Acute severe asthma</b>	<ul style="list-style-type: none"> <li>• Most common above 5 years of age</li> <li>• Known diagnosis of asthma and exposure to trigger factor</li> <li>• Difficulty in breathing/ respiratory exhaustion</li> <li>• Wheezing or chest tightness</li> <li>• Cough</li> <li>• Fast heart rate</li> <li>• Hypoxia</li> <li>• Hyperinflation of the chest</li> <li>• Confusion or drowsiness</li> </ul>
<b>Pleural effusion</b>	<ul style="list-style-type: none"> <li>• Cough</li> <li>• Rapid breathing</li> <li>• Wheeze</li> <li>• Chest pains</li> <li>• Vomiting</li> <li>• Fever (if empyema/ parapneumonic effusion)</li> <li>• Unilateral abnormal air entry</li> <li>• Unilateral dull percussion</li> </ul>
<b>Tuberculosis</b>	<ul style="list-style-type: none"> <li>• History of exposure (usually in a confined space)</li> <li>• Stridor</li> <li>• Wheeze</li> <li>• Hypoxia</li> <li>• Difficulty breathing or rapid breathing</li> </ul>

<b>Pneumothorax</b>	<ul style="list-style-type: none"> <li>• Sudden onset of difficulty in breathing</li> <li>• Wheeze</li> <li>• Hypoxia</li> <li>• Unilateral abnormal air entry</li> <li>• Unilateral hyper-resonant percussion</li> <li>• Tracheal deviation (indicates tension pneumothorax requiring immediate decompression)</li> </ul>
<b>Anaphylaxis</b>	<ul style="list-style-type: none"> <li>• Sudden onset</li> <li>• Airway compromise (swelling, stridor, hoarse voice)</li> <li>• Rapid breathing</li> <li>• Wheeze</li> <li>• Cyanosis/ hypoxia</li> <li>• Cardiovascular collapse (pale, clammy, low blood pressure)</li> <li>• Skin changes/ rashes</li> </ul>
<b>Upper airway conditions: e.g. airway foreign body, croup, epiglottitis, tracheitis</b>	<ul style="list-style-type: none"> <li>• Foreign body: sudden episode of coughing or choking, stridor, voice changes</li> <li>• Croup: stridor, barking cough</li> <li>• Epiglottitis/ tracheitis: toxic looking child, drooling</li> </ul>
<b>Other medical conditions presenting with respiratory symptoms:</b>	
<b>Gastro-oesophageal reflux disease</b>	<ul style="list-style-type: none"> <li>• Cough worse with feeds or lying flat</li> <li>• Intermittent wheeze</li> <li>• Vagally-mediated reactions (apnoea, bradycardia, laryngospasm)</li> </ul>
<b>Severe chronic anaemia</b>	<ul style="list-style-type: none"> <li>• Shortness of breath with exertion</li> <li>• Fatigue, weakness or irritability</li> <li>• Dizziness or syncope</li> <li>• Pallor</li> </ul>
<b>Severe sepsis</b>	<ul style="list-style-type: none"> <li>• Rapid breathing</li> <li>• Fast heart rate (or slow heart rate for age)</li> <li>• Fever, or low temperature</li> <li>• Presence of infection</li> <li>• Cardiovascular dysfunction (low blood pressure, prolonged capillary refill time, cold peripheries)</li> <li>• Hypoxia</li> <li>• Altered consciousness</li> </ul>
<b>Malaria</b>	<ul style="list-style-type: none"> <li>• Fever</li> <li>• Rapid breathing</li> <li>• Fast heart rate (may have circulatory collapse)</li> <li>• Altered consciousness, convulsions</li> <li>• Jaundice and abnormal bleeding</li> <li>• Children with malaria may also have severe anaemia or concomitant pneumonia</li> </ul>
<b>Heart failure and congenital cardiac conditions</b>	<ul style="list-style-type: none"> <li>• Fast breathing rate</li> <li>• Fast heart rate</li> <li>• Clammy, pale, cold peripheries</li> <li>• Weak pulses</li> <li>• Irritability</li> <li>• Limited exertion tolerance</li> <li>• Hypoxia</li> <li>• Enlarged liver</li> </ul>

**Table 2. Normal values in children<sup>14,19,26</sup>**

	Neonate	Infant	Small child	Adolescent
<b>Heart rate</b>	110-150	100-150	80-120	60-100
<b>Respiratory rate</b>	30-40	25-35	25-30	15-20
<b>Oxygen Saturation</b>	88% at sea level	Altitude greater than 2500m: SpO <sub>2</sub> > 87% Altitude less than 2500m: SpO <sub>2</sub> > 90%		
<b>Systolic Blood Pressure (lower limit, mmHg)</b>	65-75	70-80	(65+2 x age)	90

**Table 3. Definition of 'rapid breathing' and 'increased heart rate' in children<sup>26-28</sup>**

	<2 months	2-12 months	1 -5 years	>5 years
<b>Breathing Rate</b>	>60	>50	>40	>30
<b>Heart Rate (Beats per minute)</b>	>150	>150	>140	>125

**Table 4. Assessing the severity of pneumonia<sup>5,18,19,29</sup>**

Signs	Classification	Immediate treatment
Danger signs present: <ul style="list-style-type: none"> <li>• Cyanosis</li> <li>• Stridor (in calm child)</li> <li>• Somnolence</li> <li>• Lethargy</li> <li>• Difficulty drinking liquids</li> </ul>	Very severe pneumonia	If in hospital: Seek urgent senior help Give oxygen Give appropriate antibiotics IV Consider admission to Intensive Care  If not in hospital: Seek senior help urgently Give first dose of appropriate antibiotic IV. Refer urgently to hospital for IV antibiotics and oxygen.
Fast breathing Lower chest wall in-drawing	Severe pneumonia	If in hospital: Give first dose of appropriate antibiotic promptly and continue Assess need for oxygen  If not in hospital: - Give first dose of appropriate antibiotic promptly - Refer urgently to hospital for antibiotics and oxygen therapy as required
Fast breathing: >50 bpm in 2-12months >40 bpm in 1-5 years	Pneumonia (non-severe)	If no lower chest wall in-drawing or danger signs: Prescribe appropriate antibiotics Does not require hospitalisation Advise mother on supportive measures and when to return for follow-up
No fast breathing	Other respiratory illness	No need for antibiotics Does not require hospitalisation Advise mother on supportive measures and to return if symptoms worsen

so should only receive monitored oxygen therapy to maintain SpO<sub>2</sub> around 87%-94%.<sup>19</sup>

Severe pneumonia may be complicated by a collection of either fluid (parapneumonic effusion) or pus (empyema) in the pleural space, adding significantly to morbidity.<sup>37,22</sup> Exclude these complications in any child who is not responding to treatment after 48 hours. They also necessitate admission to hospital with intravenous antibiotic therapy. Chest imaging with anteroposterior or posteroanterior X-rays and ultrasound can aid diagnosis and guide thoracocentesis. Chest drains should be sited for large collections and will prompt referral to a tertiary centre. Blood, sputum and pleural fluid may be sent for microbiological evaluation if available. Remember that 6% of empyemas globally are due to tuberculosis.<sup>37</sup>

## Asthma

Acute severe asthma and life-threatening asthma are conditions of severe bronchospasm. Inflammation and mucus secretions worsen airway narrowing. It is important to realise that acute exacerbations may be life threatening – do not underestimate their severity.<sup>20,21</sup> Asthma is uncommon in children under the age of 5 years old.

A child with asthma should be assessed with an ABC approach. Clinical symptoms and signs do not always correlate well with the degree of airway obstruction. Severity classification is shown in Table 5. Pay particular attention to respiratory rate, degree of breathlessness, use of accessory muscles, amount of wheeze, heart rate and degree of agitation or drowsiness. Danger signs include a silent chest, cyanosis or low SpO<sub>2</sub>, poor breathing effort or exhaustion, low blood pressure and confusion. As asthma worsens so does the heart rate. A falling heart rate in a child with life-threatening asthma is a pre-terminal sign.<sup>21,27</sup>

Oxygen saturation monitoring is essential in all wheezy children. Peak Expiratory Flow (PEF) rate is commonly used for disease monitoring in developed countries. If the child is familiar with its use it can also provide additional information in the acute exacerbation, but is not essential.

For children under the age of 2 years the primary cause of intermittent wheeze is usually viral infections. Very few will have wheeze due to asthma.<sup>27</sup>

The child with an acute severe exacerbation of asthma needs immediate medical attention, assessment and treatment. It can be a frightening situation, not only for the child and their carers, but also for hospital staff, so call for senior help immediately. Keep calm so as not to distress the child further. Allow the child to position itself in the most comfortable posture, which is often sitting upright, to reduce respiratory distress and improve chest wall movement.

Management of asthma is shown in Box 3. Treatment aims to reverse bronchospasm so that normal respiratory gas exchange is restored. Use bronchodilators to relieve bronchospasm, steroids to reduce bronchial oedema, and treat any infection if present. The majority of acute asthma attacks are triggered by viral infection so antibiotics should not be given routinely.<sup>27</sup> Avoid any drugs that are known to release histamine, as they will worsen bronchospasm. Consider medications such as magnesium, salbutamol, aminophylline and

ketamine if initial treatments fail and appropriate HDU/ICU level care and monitoring is available. The indications for admitting a child to PICU are shown in Box 4.

Chest Xrays are not routinely necessary. Use them for signs of surgical emphysema, persistent signs of pneumothorax, consolidation or if life-threatening asthma is not responding to treatment.<sup>27</sup>

For children under two years, response to treatment can be unpredictable. First line treatment of salbutamol given via an inhaler and spacer with a close fitting mask is better than nebulizer.<sup>27</sup> Ipratropium may be beneficial to infants with severe symptoms. Steroids should be given (10mg soluble prednisolone for up to three days). After discharge it is not usually necessary to continue bronchodilator therapies in this age group.

## Bronchiolitis

Bronchiolitis is diagnosed on the basis of clinical features. The child is usually between 3-6 months old and certainly under the age of two years old. High fever is uncommon and temperatures > 39°C should prompt evaluation for other causes. Danger signs are shown in Table 6.

The principle of managing bronchiolitis is providing supportive care since there are no effective therapies (Box 5). Admission to hospital is often necessary because the baby is unable to feed due to respiratory distress, and for administration of oxygen. As far as possible, give enteral (oral or nasogastric) fluids and feed. If the child is too sick to tolerate enteral feed, give intravenous fluids at 2/3 maintenance rate. For calculation of fluid requirements see 'Recognising the Critically Ill Child' article in this edition of *Update*, page 224.

Approximately 2% of infants will require ventilatory support. CPAP may reduce the need for intubation and ventilation. Look out for any infant who is tiring or has other danger signs indicating the need for intubation or PICU admission. (See Box 6).

Routine antibiotics are not recommended.<sup>17,38</sup> Children requiring ventilatory support or with more serious illness may have co-existing bacterial infections, so empirical antibiotic cover is reasonable in these children.

One or two doses of 3% saline administered through a nebuliser may increase the clearance of mucus in children with non-severe bronchiolitis presenting to hospital. Evidence suggests a shorter hospital stay with no significant adverse effects. Further research is required to determine the safety profile of nebulised hypertonic saline.<sup>39</sup>

The wheeze in bronchiolitis is mainly caused by debris in the airway, unlike the bronchospasm seen with asthma. Bronchodilators are not recommended due to their lack of efficacy, cost and side-effects (rapid heart rate and shakiness).<sup>8,17</sup>

Current evidence implies possible positive short-term benefit of steroids for inpatients with bronchiolitis, but long-term outcomes are unchanged.<sup>40</sup> Although some research indicates that the combination of steroids used with epinephrine nebulisers may reduce outpatient admissions, long term effectiveness and safety still

**Table 5. Assessing the severity of asthma in children > 2 years old<sup>21,27</sup>**

Symptoms and Signs	Classification	Immediate treatment
'Danger signs': <ul style="list-style-type: none"> <li>• Silent Chest</li> <li>• Cyanosis or low saturation (SpO<sub>2</sub> &lt;92%)</li> <li>• Poor respiratory effort</li> <li>• Low blood pressure</li> <li>• Exhaustion</li> <li>• Confusion</li> <li>• PEF &lt;33% predicted/best</li> </ul>	Life threatening	Seek urgent senior help Continue management as for severe asthma Consider adjuncts, intubation and ventilation. Needs ICU admission
<ul style="list-style-type: none"> <li>• Can't complete sentences or unable to feed</li> <li>• PEF 33-50% of predicted/best</li> <li>• Fast breathing:                             <ul style="list-style-type: none"> <li>- &gt;50 bpm 2-12month old</li> <li>- &gt;40 bpm 1-5 year old</li> <li>- &gt;30 bpm &gt;5 year old</li> </ul> </li> <li>• Fast heart rate                             <ul style="list-style-type: none"> <li>- &gt;140 2-5 year old</li> <li>- &gt;125 &gt;5 years year old</li> </ul> </li> </ul>	Severe	Seek urgent senior help Check ABC Administer oxygen Nebulised salbutamol 2.5-5mg (or 2 puffs of inhaler via spacer every 2 mins up to 10 puffs) Nebulised ipratropium bromide
<ul style="list-style-type: none"> <li>• Able to talk in sentences or feed well</li> <li>• SpO<sub>2</sub> &gt;92%</li> <li>• PEF &gt;50% predicted/ best</li> <li>• Fast breathing but:                             <ul style="list-style-type: none"> <li>- &lt;50 bpm 2-12month old</li> <li>- &lt;40 bpm 1-5 year old</li> <li>- &lt;30 bpm &gt;5 year old</li> </ul> </li> <li>• Fast heart rate, but:                             <ul style="list-style-type: none"> <li>- &lt;140 in 2-5 year old</li> <li>- &lt;125 in &gt;5 year old</li> </ul> </li> </ul>	Moderate	Administer Oxygen Nebulised Salbutamol 2.5-5mg (or 2 puffs of inhaler via spacer every 2 mins up to 10 puffs) Nebulised Ipratropium

requires further research and adrenaline nebulisers are not routinely recommended.<sup>17,40,41</sup> There is insufficient evidence to support the use of adrenaline in inpatients, but it may be of value in the outpatient setting.<sup>41</sup>

## ADVANCED VENTILATORY SUPPORT IN CHILDREN WITH ALRI

Advanced ventilatory support necessitates high-dependency or paediatric intensive care admission. The main options are either non-invasive or invasive ventilation.

### Non-invasive ventilation

Non-invasive ventilation relies on augmenting the child's own respiratory effort to reduce the work of breathing. Continuous Positive Airway Pressure (CPAP) acts as its name suggests by administering a

continuous positive pressure of between 5-10 cmH<sub>2</sub>O to keep alveoli open, reduce sheering injury and allow improved oxygenation. CPAP can be administered via nasal prongs in infants or through a tight fitting facemask in older children. Low cost systems are available. Non-invasive positive pressure ventilation (NIPPV) administers an alternating inspiratory and expiratory pressure triggered by the patient's own breathing efforts. It is particularly useful for aiding carbon dioxide clearance. Non-invasive techniques may reduce the need for intubation and ventilation.

### Invasive ventilation

Invasive ventilation requires intubation with an endotracheal tube. There are numerous ventilation modes and equipment available. The choice of technique will depend on clinician experience, equipment availability and the child's clinical condition. Lung-protective strategies should be used (Box 7). The process of intubating a

### Box 3. Management of acute severe asthma<sup>15,21,27</sup>

#### Initial management of acute severe asthma:

- Asses ABC and administer high flow oxygen
- Nebulised salbutamol (2.5-5mg) or 10 puffs administered via an inhaler and spacer
- Nebulised ipratropium bromide (250 micrograms)
- Oral prednisolone 20mg (2-5years), 30-40mg (>5year). Use hydrocortisone 4mg.kg<sup>-1</sup> IV if unable to take orally
- Review response to treatment. Repeat ABC assessment

#### If there is no improvement:

- Adrenaline IM 10 micrograms.kg<sup>-1</sup> (consider IV adrenaline infusion only if specialized syringe pumps and continuous electrocardiography monitoring are available)
- IV salbutamol bolus dose (15mcg.kg<sup>-1</sup> over 10 min)
- IV aminophylline
- IV magnesium sulphate 40mg.kg<sup>-1</sup> (max 2g)
- Ketamine or volatile agents may assist in relieving intractable bronchospasm

#### Subsequent management:

- Rehydrate with 10-20ml.kg<sup>-1</sup> crystalloid
- Oral prednisolone 20mg (2-5years), 30-40mg (>5year) for three days
- Repeat nebulisers every 20-30 minutes if required, or 3-4 hourly
- Perform a chest X-ray and arterial blood gases if life-threatening asthma is not responding to treatment
- Consider admission to PICU for non-invasive ventilation or intubation and ventilation

### Box 4. Indications for admission to ICU for children with asthma<sup>15</sup>

- The child has severe acute- or life-threatening asthma
- The child is not responding to treatment
- Persistent or worsening hypoxia
- Hypercarbia
- Falling pH on arterial blood gases
- Exhaustion, feeble respiration, drowsiness or confusion

critically ill child can provoke cardiorespiratory instability and an initial deterioration. Be prepared for potential complications as well as competent in the management of the paediatric airway. Positive pressure ventilation may also reduce venous return to the heart thus causing low blood pressure.

In cases of severe refractory hypoxia, consider high frequency oscillation (HFO) if available. This acts on the 'open lung strategy' by providing a continuous distending pressure around which oscillations of a frequency of >150 per minute allow gas exchange.<sup>15</sup>

#### Invasive ventilation - special considerations

##### *Asthma*

If a child with life-threatening asthma fails to respond to maximal

medical treatment, the decision to intubate and ventilate should be based on the following criteria:

- Availability of Paediatric Intensive Care facilities
- Respiratory arrest
- Hypoxia and rising hypercarbia
- Exhaustion
- Altered mental state.

Intubation risks significant complications, which you should anticipate and plan for. These include worsening of bronchospasm, laryngospasm, worsening hypoxia, pneumothorax and barotrauma, and hypotension due to reduced venous return.

**Table 6.** Assessing the severity of bronchiolitis<sup>15,17</sup>

Symptoms and Signs	Classification	Immediate treatment
Danger signs: Breathing Rate >70bpm Periods of apnoea Infant looks ill and exhausted Sweaty and irritable Atelectasis, marked over- inflation or evidence of ARDS on CXR	Severe	Seek urgent senior help Administer oxygen Assess need for ventilatory support or admission to PICU
Fast breathing rate Increased effort of breathing Cough Wheeze Hyperinflation of the chest Fast heart rate	Moderate	Consider admission to hospital Administer oxygen if required Maintain hydration

**Box 5.** Management of bronchiolitis

- Assess ABC
- Administer oxygen to maintain appropriate saturations
- Maintain hydration:
  - Attempt to hydrate with oral or NG fluids
  - IV fluids may be required if the child is too sick to take oral or NG feed
  - Restrict IV fluids to 2/3 maintenance
- Review indications for ventilation and PICU admission
- Consider nebulised adrenaline

**Box 6.** Indications for PICU admission in children with bronchiolitis<sup>15</sup>

- Increasing oxygen requirement or inability to maintain adequate oxygen saturation in high flow oxygen
- Signs of becoming exhausted
- Progressive rise in PaCO<sub>2</sub>
- Apnoeas

Process of intubation:

- Ensure good intravenous access
- Give IV fluid bolus 10ml.kg<sup>-1</sup> of crystalloid
- Pre-oxygenate for 3 minutes with tight fitting mask
- Use ketamine for induction as it has bronchodilator effects (2mg.kg<sup>-1</sup>)
- Use a cuffed endotracheal tube as high inflation pressures may be required
- Avoid rapid ventilation of the child once intubated as this will lead to air trapping, increase the risk of pneumothorax and worsen gas exchange. Use a slow rate with a long expiratory time
- If severe air trapping does occur, disconnect the child from the ventilator and physically squeeze on the chest to assist expiration
- Always perform a chest X-ray after intubation to confirm the correct position of the endotracheal tube and to carefully check for pneumothorax which will worsen with positive pressure ventilation

**Table 7. Ventilation in acute severe asthma<sup>42</sup>**

		<b>Rationale</b>
<i>Mode of ventilation</i>	Pressure Controlled (PC)	The decelerating waveform results in lower inspiratory pressures for a given mean airway pressure
	Volume Controlled (VC) Aim for tidal volume 4-8ml.kg <sup>-1</sup>	PC is preferable but VC may be used.
<i>Rate</i>	Slow for age 5-15 breaths per minute	A slow rate reduces air-trapping
<i>Inspiratory time</i>	Suggested 1.0-1.5 seconds	
<i>I:E Ratio</i>	1:3 - 1:5	Long expiratory time helps avoid dynamic hyperinflation
<i>Positive Inspiratory Pressures (PIP)</i>	Limit PIP < 35cmH <sub>2</sub> O Limit inspiratory plateau pressure <30 cmH <sub>2</sub> O	High inspiratory pressures are likely to be required
<i>PEEP</i>	Avoid high PEEP	High PEEP will worsen hyperinflation and air trapping

**Box 7. Principles of lung protective ventilation<sup>15,42</sup>**

The main aim is to optimise lung mechanics to reduce parenchymal damage, accepting altered physiological goals.

Avoid the following:

#### **Barotrauma**

High pressures over-stretch healthy lung:

Maintain plateau airway pressures <30cmH<sub>2</sub>O

Maintain peak airway pressures <35cmH<sub>2</sub>O

#### **Volutrauma**

High tidal volumes cause sheering injury to the alveoli:

Maintain tidal volumes 4-8ml.kg<sup>-1</sup>

#### **Hyperoxia**

Hyperoxia worsens atelectasis and inflammatory changes. Use the minimum oxygen required to maintain oxygen saturations:

If possible keep FiO<sub>2</sub> ≤0.4

Consider the following:

#### **PEEP to recruit alveoli**

Avoid in conditions which have high intrinsic PEEP such as acute severe asthma

#### **Permissive hypercapnoea**

Accept high PaCO<sub>2</sub> if pH normal or near normal (>7.2)

#### **Relative hypoxia (accept SpO<sub>2</sub> 85-90%)**

Optimise oxygen delivery (Cardiac output, Haemoglobin) and if possible, use lactate level to assess organ perfusion.

Ventilation of a child with asthma can be difficult. Due to the tight bronchoconstriction, high pressures may be required. Be careful to use techniques to limit barotrauma and air trapping which are common in asthma. Hypercarbia can be tolerated so long as the pH remains >7.2. Table 7 shows suggestions for ventilating such a child.

Continue bronchodilators during ventilation. Administer by nebulised form via the breathing system or as intravenous infusions.

Ketamine (0.5-2mg.kg<sup>-1</sup>.hour<sup>-1</sup>) may be used as a sedative, either alone or with morphine/midazolam.

If the patient remains hypoxic, investigate for pneumothorax and signs of infection. Evaluate the use of beta2-agonists, which may worsen VQ mismatch in the presence of hypovolaemia.

### Bronchiolitis

In bronchiolitis, the primary difficulty is achieving adequate oxygenation. High inspiratory pressures may be required. Low respiratory rates with long inspiratory times will help to allow adequate tidal volumes while reducing the risk of barotrauma to the lungs. Positive End Expiratory Pressure (PEEP) of 5-10cmH<sub>2</sub>O will prevent alveolar collapse and further aid oxygenation.

### CONCLUSIONS

Poverty is a substantial risk factor for many diseases, both infectious and non-communicable. Not only are the poor more vulnerable to developing disease, but they are also least likely to be able to access, afford and receive adequate treatment. All children presenting with acute lower respiratory tract disorders should be managed with the same systematic (ABC) approach. Following diagnosis, the key is to deliver prompt treatment, regularly reassess the child's response to treatment and watch for signs of deterioration, which may necessitate admission to intensive care facilities. Development of guidelines will improve the quality of treatment delivered, thereby reducing morbidity and mortality.

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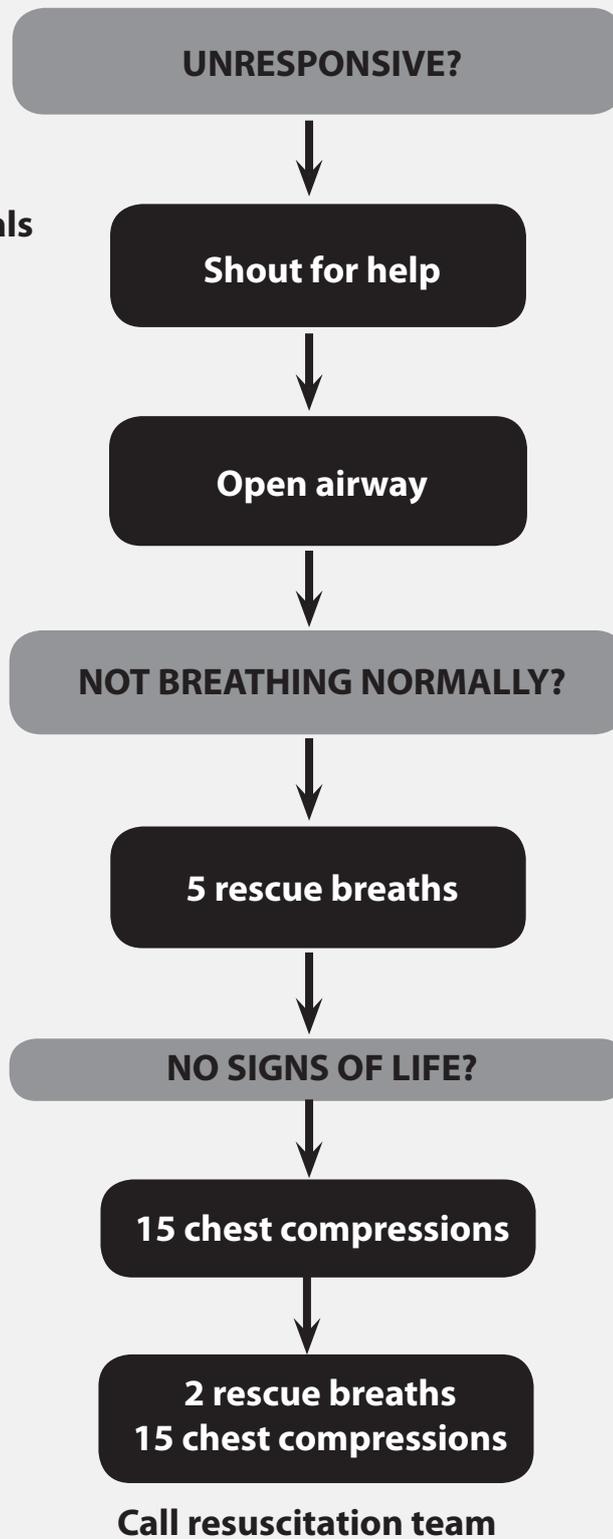
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# Paediatric Basic Life Support

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