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desaturations below 90%. The measure that correlates best with poor academic performance is the lowest level of SpO₂ (nadir) during the night (normal value is > 87.5%).

Adverse effects of hypoxaemia
These include the following:
- poor weight gain
- developmental delay
- poor cognitive function
- pulmonary hypertension
- cyanotic apnoeic episodes.

Treatment
- Time: the airway enlarges with growth.
- Obstruction is worse with infections and may need a rescue course of steroids (e.g. prednisolone 0.5 mg/kg once daily for up to 7–10 days).
- Topical steroids/decongestants.

Nasal CPAP (see Section 1.25)
This is an effective non-invasive treatment, but it is associated with the following potential problems:
- compliance
- side effects:
  - skin sores
  - nose bleeds
  - conjunctivitis
  - aerophagy.

Reference

5.2 Lower airway disorders

5.2.A Bronchiolitis

80X 5.2.A.1 Minimum standards
- Oxygen.
- Oxygen saturation monitor.
- Bag-valve-mask system.
- Cannulae for thoracostomy.
- Antibiotics.
- Nasal CPAP.

Introduction
Wheezing is a whistling noise heard during expiration. The child who has cough or difficulty breathing and wheezing will fit into one of the following categories:
- bronchiolitis (mainly less than 1 year old)
- asthma (over 1 year old)
- pneumonia with wheezing (any age).

In pneumonia with wheezing in children over 1 year of age and in asthma, a bronchodilator provides important symptomatic relief. An aerosol and large-volume spacer (which may be improvised) is the best way of administering a bronchodilator (see below). Bronchodilators are not routinely effective in bronchiolitis, but may be tried in some cases.

A lower respiratory viral infection, typically most severe in young infants, occurs in annual epidemics, and is characterised by airways obstruction and wheezing. Respiratory syncytial virus is the most important cause. Secondary bacterial infection may occur and is common in some settings. Episodes of wheeze may occur for months after an attack of bronchiolitis, but will eventually stop. Some babies who have had bronchiolitis go on to have asthma, but both bronchiolitis and asthma are common conditions, and a causal relationship has not been established.

Clinical features of bronchiolitis
- Infants are coryzal, have a troublesome cough and may feed poorly or even be unable to suck and feed. There may be vomiting.
- The nose is often obstructed by secretions.
- On examining the chest, there may be hyperinflation, chest wall indrawing, nasal flaring, grunting, wheeze and fine crackles at the lung bases.
- Young infants may present with apnoeic/hypoxaemic episodes which may be recurrent and life-threatening.
- There may be hypoxaemia, with SaO₂ less than 94%, with or without cyanosis.
- Some infants will have such severe respiratory distress that there is gasping; this is pre-terminal.

Treatment
Only supportive treatment (e.g. oxygen, gentle suction of the nose, and fluids) is of benefit. Antibiotics and bronchodilators have no role. However, in the most severe cases and unless you are certain that pneumonia is not present,
it is safer to give antibiotics and a trial of a bronchodilator (stop the bronchodilator if it is not helping).

Non-invasive respiratory support to help to overcome small airway obstruction (nasal CPAP and continuous negative extrathoracic pressure (CNEP)) may be valuable (see Section 1.25 and Section 8.3). CNEP may be more effective because of the nasal blockage that accompanies bronchiolitis.

- Give oxygen by nasal cannulae to keep \( \text{SaO}_2 \) in the range 94–98%. Check that the nasal cannulae are in the correct place, and check frequently that they are not blocked by secretions.
- Nasal clearance. Gentle nasal suction should be used to clear secretions in patients in whom nasal blockage is thought to be causing respiratory distress. This may be aided by saline nasal drops or spray.
- Ensure that daily maintenance fluids are achieved. If this is not possible by mouth, use nasogastric feeding. This should be considered in any patient who is unable to maintain oral intake or hydration (use the mother’s expressed breast milk if possible and if tolerated).
- If the patient is vomiting despite nasogastric feeding, or severe respiratory distress is present, give fluids IV.
- If there are signs of pneumonia, give antibiotics (see Section 5.3.A).
- If fever (\( \geq 39^\circ\text{C} \) or \( \geq 102.2^\circ\text{F} \)) is causing distress, give paracetamol. High fever is the exception rather than the rule in bronchiolitis, and should make you suspect bacterial infection.

**Failure to improve**

If the condition worsens suddenly, consider pneumothorax, although this is uncommon. Tension pneumothorax associated with major respiratory distress and shift of the heart requires immediate relief by needle thoracocentesis (i.e. placing a needle to allow the air that is under pressure to escape) (see Section 8.3). If needle thoracocentesis is helpful, insert a chest tube with an underwater seal until the air leak closes spontaneously and the lung expands (see Section 8.3). The signs of pneumothorax in severe bronchiolitis may be difficult to detect clinically. However, needle thoracocentesis in the absence of a pneumothorax may cause one, so if you are unsure, take a chest X-ray. Even on a chest X-ray, the diagnosis may be very difficult due to the areas of hyperlucency in bronchiolitis caused by air trapping.

If respiratory failure develops, nasal continuous positive airsweeps pressure (CPAP) or continuous negative extrathoracic pressure (CNEP) may be of benefit (see Section 8.3).

If apnoeic episodes develop (this is most likely in premature infants), give bag-valve-mask resuscitation, then nasal CPAP or CNEP. Sometimes intubation and ventilation may be needed in a high-dependency ward (if available); if so, contact an anaesthetist urgently.

**Infection control**

Bronchiolitis is infectious and easily transmitted to other infants and young children in hospital. Babies in the neonatal unit are particularly at risk. The following strategies may reduce the risk of cross-infection (see Section 1.2):
- hand washing between patients
- the wearing of gloves and aprons
- ideally isolate the affected patient, but close observations are needed
- restrict visiting by anyone with symptoms of upper respiratory tract infection.

### Section 5.2

#### 5.2.B Asthma

**BOX 5.2.B.1 Minimum standards**

- Inhaled bronchodilators (with spacers).
- Inhaled steroids.
- Prednisolone/hydrocortisone.
- Nebulised bronchodilators.
- Oxygen.
- Salbutamol, magnesium sulphate, adrenaline and aminophylline.
- Pulse oximetry.

**Introduction**

Asthma is a condition characterised by episodic or recurrent symptoms of cough, prolonged expiration with wheeze, chest tightness and shortness of breath without fever (although some episodes are precipitated by an upper respiratory tract infection which may have an accompanying fever). It is due to variable and reversible airway obstruction associated with chronic airway inflammation. Asthma has become more prevalent over the last 20 years, along with the other atopic conditions such as allergic rhinitis and eczema. This is particularly so in well-resourced countries, where it is reported to occur in up to 10–15% of children.

Young children (under 5 years of age) often have ‘asthma-like’ symptoms (cough, wheeze and shortness of breath) in response to respiratory infections, but with no demonstrable problem between infections. This tendency often stops in the early school years. In these children, treatment of episodic symptoms with acute asthma therapies (‘relievers’) may still provide relief of symptoms, but ‘preventers’ (i.e. inhaled steroids) will not usually be of benefit unless the child has continuous symptoms or is likely to be atopic (e.g. due to a personal or family history of asthma, eczema or allergic rhinitis). In the youngest children (less than 2 years old) with severe episodes or symptoms continuing between infections (interval symptoms), it is necessary to consider other diagnoses, such as bronchiectasis, tuberculosis, foreign body and cystic fibrosis.

**Diagnosis of asthma between episodes**

The diagnosis is clinical, and is based on a history of the following:
- recurrent cough (mostly dry, becoming productive with exacerbations), wheeze, shortness of breath or chest tightness
- symptoms worse at night, and on exertion
conditions other than asthma may also show reversibility. Without steroids support the diagnosis, but bear in mind that skin prick tests, or IgE RASTs, do not aid the diagnosis, and only infrequently help in the management.

Examination may identify any of the following:
- No abnormalities
- Slow growth
- Overinflation of the chest, Harrison’s sulci
- Wheeze, particularly on forced expiration
- Rhinitis or eczema.

Investigations
Investigations are not usually needed, but may help to support the diagnosis or exclude other conditions:

1. Chest X-ray. This is normal or shows overinflation (flat diaphragms and hyperlucency, particularly when severe or acute), or increased perihilar linear markings.
2. Peak flow (in children aged 7–8 years or over). This may show the following:
   - More than 15% variability from morning to night (keep a peak flow diary)
   - A fall after 5–10 minutes of hard exercise
   - A rise after a dose of inhaled bronchodilators (e.g. salbutamol)
   - Spirometry will show FEV1:FVC of less than 85% and concavity in the flow-volume loop, which is at least partially reversed by a dose of inhaled bronchodilators.

Skin prick tests, or IgE RASTs, do not aid the diagnosis, and only infrequently help in the management. Symptoms that resolve with bronchodilators with or without steroids support the diagnosis, but bear in mind that conditions other than asthma may also show reversibility.

Ongoing management
- Avoid allergic/irritant factors (e.g. smoke, chemical fumes, house dust mites, animal fur). Discourage cigarette smoking and acquiring new pets at home.
- Do not prevent the child from exercising, but pre-dose them 5–10 minutes beforehand with a dose of inhaled beta-2 agonist bronchodilators (e.g. salbutamol).

Use of ‘reliever’ medication
- Occasional symptoms (e.g. on 2 to 4 days per week) may be managed with only the use of a bronchodilator (a ‘reliever’), and do not usually need a ‘preventer’ (see below).
- Use inhaled drugs where possible, except in acute severe or life-threatening attacks, when the IV route may be used.
- Use an aerosol spray (metered-dose inhaler) with a spacer (first choice):
  - A commercial medium- to large-volume spacer (e.g. Volumatic, AeroChamber), or a large (2-litre) plastic bottle with the aerosol sealed into one end, and the open end held closely over the nose and mouth (see Figure 5.2.B.1).
  - Use 200–1000 micrograms of salbutamol (2–10 sprays); more may be needed in younger children, or if the patient is acutely breathless (and repeated).
  - Each spray or puff should be inhaled individually in turn with 4 to 5 breaths, rather than filling the spacer device with multiple sprays.
  - For children under 5 years of age, attach a face mask (e.g. inverted adult mask) to the mouthpiece of a spacer.

Clean the spacer with soapy water and leave it to dry naturally to reduce static electrical charges on the inside. Alternatively, use a nebuliser to deliver salbutamol (this is less portable).

Children with asthma should always have immediate access to their usual reliever inhaler device. Children over 7–8 years of age may keep their device with them.

Use of ‘preventer’ medication
More frequent symptoms, regular nocturnal symptoms or daily use of a bronchodilator should be treated with regular medication aimed at controlling airway inflammation (a ‘preventer’), such as inhaled steroids. Use inhaled (preferably through a spacer) beclomethasone propionate or budesonide, 200–400 micrograms twice daily.
- Rinse the mouth (if feasible) after each dose of inhaled steroid.
- Aim for rapid control of symptoms, and then tail down the dose over a period of months.
- Gaining control may be helped by a short course (7–10 days) of systemic steroid (e.g. prednisolone 500 micrograms/kg once daily after food or milk, maximum daily dose 40mg).
- Continue with bronchodilator use for symptom relief (but avoid regular use).

For frequent or severe symptoms, consider:
- Whether the diagnosis is correct
- Aggravating factors (e.g. rhinitis, stress, gastro-oesophageal reflux)
- Whether the medication is being taken, and whether it is being taken correctly
- Increasing the inhaled steroid dose (beclomethasone to 400–800 micrograms twice daily) or adding leukotriene antagonists (e.g. montelukast), which are useful in preschool children, or a long-acting inhaled drug (e.g. salmeterol) or oral methylxanthines (e.g. theophylline 5 mg/kg three to four times a day)
- As a last resort, use of alternate-day oral prednisolone (start at 500 micrograms/kg on alternate days and reduce rapidly to 100 micrograms/kg on alternate days, to the nearest 1 mg or 5 mg tablets). Stop as soon as possible.

Children on inhaled or oral steroids should have regular...
checks of their growth and be watched for steroid side effects (e.g. oral thrush).

The control of asthma should be regularly reviewed (e.g. 3-monthly) and medication stepped up or down depending on the symptoms and on peak flow measurements or spirometry in those over 7 years of age. Families should be given written instructions and helped to change the treatment themselves, with support.

Management of an episode of acute asthma

Initial treatment of a mild to moderate acute attack of asthma is as follows:

- Reassure the child and their parents, and avoid upset as this may exacerbate respiratory distress.
- Give a regular inhaled beta-2 agonist bronchodilator, such as salbutamol aerosol 200–1000 micrograms (2 to 10 sprays each of 100 micrograms, with each spray given after every four to five breaths) via a spacer every 30 minutes to 2-hourly until the child is better.
- If the child does not respond to the spacer, give 2.5 mg salbutamol for children under 5 years and 5 mg salbutamol for those over 5 years via a nebuliser 2- to 4-hourly (use oxygen to drive the nebuliser if possible).
- Give systemic steroids: oral prednisolone 1 mg/kg (maximum dose of 40 mg) for 3–5 days, depending on the duration of symptoms; administer with food or milk to avoid gastric irritation.
- Treat or remove any exacerbating factors (see the ‘Diagnosis’ section above).
- Give antibiotics only if there are signs of pneumonia, especially a persistent fever.

Very severe or life-threatening asthma

Features of severe or life-threatening asthma include the following:

- being too breathless to feed, drink or talk
- marked recession/use of accessory muscles
- respiratory rate of more than 50 breaths/minute
- pulse rate of more than 140 beats/minute
- poor chest movement or silent chest
- exhaustion, agitation or reduced conscious level (due to hypoxia or hypercapnia)
- hypoxaemia (SaO₂ less than 90% in air or cyanosis) (this is a very late sign).

Treat immediately (use the ‘ABC’ approach):

- Give 100% oxygen via a face mask with reservoir bag held by the parent or nurse close to the child’s face at 10–15 litres/minute to keep SaO₂ in the range 94–98%.
- Give salbutamol inhaled from a nebuliser, 2.5 mg nebulules for children under 5 years and 5 mg for those over 5 years, and repeated as required (drive the nebuliser with oxygen at 6–8 litres/minute rather than compressed air). Sometimes nebulisers may be needed continuously (described as ‘back to back’, i.e. as each nebulule finishes, repeat with another).
- If a nebuliser is not available, use inhaled salbutamol via a spacer (but now without a valve that needs opening with each breath; see Figure 5.2.B.1, in which the home-made ‘spacer’ has no valve) as described above in acute asthma. That is, give salbutamol aerosol 1000 micrograms (10 sprays each of 100 micrograms, with each spray given after every four to five breaths) via the spacer every 5–10 minutes initially and then, once there is some improvement, 10 sprays over four to five breaths each, every 10–30 minutes until the child is better. Children under 4 years of age are likely to require a face mask connected to the mouthpiece of a spacer for successful drug delivery. Inhalers should be sprayed into the spacer in individual sprays and inhaled immediately by tidal breathing.
- If nebulised or inhaled beta-agonist bronchodilators are not available or are not effective and the child is deteriorating, give an intramuscular injection of adrenaline: 10 micrograms/kg (0.01 mL of Ag of 1 in 1000 solution, up to a maximum of 300 micrograms), measured accurately with a 1-ml syringe (ensure that the needle is not in a vein before injecting). If there is no improvement after 15 minutes, repeat the dose once.

In addition to the bronchodilator treatment, give systemic steroids either as IV/IM hydrocortisone 4 mg/kg 4- to 6-hourly (preferable) or as oral prednisolone (see above) until recovery. Start the steroids as soon as possible. A soluble preparation dissolved in a spoonful of water is preferable in those unable to swallow tablets. Use a dose of 20 mg for children aged 2–5 years. Repeat the dose of prednisolone in children who vomit, and give IV (or IM if a venous cannula cannot be inserted) hydrocortisone (4 mg/kg repeated 4-hourly) in those who are unable to retain orally ingested medication. Treatment for 3–5 days is usually sufficient, but the length of the course should be tailored to the number of days necessary to bring about recovery. Weaning is unnecessary unless the course of steroids exceeds 14 days.

If two to three doses of inhaled bronchodilator and systemic steroids do not result in improvement, or if life-threatening features are present, use:

- IV beta-2-agonist salbutamol (loading dose 5 micrograms/kg over 10–15 minutes in children under 2 years of age and 15 micrograms/kg over 2 years of age). If resources allow (i.e. only where high-dependency or intensive care is available), this can be followed by 1–2 micrograms/kg/minute (maximum of 5 micrograms/kg/minute) adjusted according to response and heart rate, and with monitoring of serum potassium levels as this electrolyte falls when salbutamol is given IV (see below).
- or IV magnesium sulphate 40 milligrams/kg (maximum of 2 grams) over 20 minutes
- or both of the above

Severe and life-threatening hypokalaemia may occur with IV salbutamol, potentiated by steroids. If possible, monitor the ECG continuously and check potassium levels 12-hourly. ECG signs of hypokalaemia are ST depression, T-wave...
High-flow oxygen by mask held close to nose and mouth
Salbutamol by spacer (see drug list below)

Back to oxygen by nasal cannulae

Is the child improving?

YES

NO

Repeat salbutamol by spacer 1- to 2-hourly
Oral prednisolone once daily

Repeat as long as improving

Nebulised salbutamol driven by oxygen
2.5 mg less than 5 years and 5 mg for 5 years or older
or continuous salbutamol spacers

Continuous nebulised salbutamol
IV/IM hydrocortisone 4 mg/kg or oral prednisolone if not vomiting

Drugs in asthma
Salbutamol
- Inhaled by spacer without valve: give a spray of 100 micrograms into spacer after every 4–5 breaths. Initially give 10 sprays (i.e., over 40 to 50 breaths) and then wait 10 minutes, review, and repeat every 10–30 minutes as necessary
- Nebuliser: 2.5 mg/5 ml for < 5 years old
- Nebuliser: 5 mg/5 ml for ≥ 5 years old
- IV loading: 1 month to 2 years, 5 micrograms/kg; 2–18 years, 15 micrograms/kg
- IV infusion: 1–2 micrograms/kg/minute according to response, heart rate and serum K⁺ level (essential)

Aminophylline
- Loading: 5–6 mg/kg over 20–60 minutes (maximum dose = 300 mg)
- Infusion: 1 mg/kg/hour

Magnesium sulphate
- Loading: 40 mg/kg (maximum 2 grams) over 20 minutes by IV infusion

Adrenaline
- 10 micrograms/kg IM or SC

Steroids
- Hydrocortisone 4–8 mg/kg IV (maximum 300 mg)
- Prednisolone 1 mg/kg orally

Omit loading dose of aminophylline if any has been given in preceding 24 hours
Stop infusion if patient vomits, heart rate >180 beats/minute, convulsions or headache

FIGURE 5.2.B.2 Pathway of care for very severe or life-threatening asthma.

Transcutaneous pCO₂ monitoring is valuable in severe asthma.
In cases that do not respond to the above measures, obtain a chest X-ray and consider mechanical ventilation (slow rate, long expiration). A blood gas measurement showing respiratory acidosis can be valuable at this time, but remember that invasive procedures can worsen respiratory distress.

If intubation and ventilation become essential, ketamine induction followed by inhalational anaesthetic gases (e.g., halothane) may assist bronchodilatation.

Indications for intubation and ventilation (if available) in severe asthma include the following:
- increasing exhaustion
- progressive deterioration in clinical condition
- oxygenation decreasing and/or oxygen requirement increasing

reduction and prominent U waves. Ensure that maintenance potassium intake is given in the infusion fluid.

If there is a poor response to the above treatment, or the child’s condition worsens suddenly, obtain a chest X-ray to look for evidence of pneumothorax. In the presence of hyperinflation from asthma, detection of a pneumothorax on the chest X-ray may be difficult.

Monitor the above clinical features regularly, and also monitor oxygen saturation, by pulse oximeter if available. Keep SaO₂ in the range 94–98% by administering oxygen, either by face mask or by nasal cannulae. Use oxygen to drive nebulisers.

If the above measures do not result in improvement, or the child is tiring and gasping, this may progress to a respiratory arrest. Positive airway pressure would be the usual next step. Some respiratory support can be given by the use of a bag-valve-mask system to increase tidal breaths, but beware of aspiration (insert a nasogastric tube).
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- pCO₂ increasing (if measurable from arterial/capillary gas)
- sudden deterioration – and always consider the possibility of a pneumothorax.

Follow-up care

Once the child has improved sufficiently to be discharged home, prescribe inhaled salbutamol through a metered-dose inhaler with a suitable commercially available or home-made spacer (see Figure 5.2.B.1), and instruct the parents in how to use this.

Following any acute episode, review asthma control and management, including correct use of medications and the need for a step up in "preventive" treatment.

5.2.C The child with an inhaled foreign body

**BOX 5.2.C.1 Minimum standards**
- Chest X-ray.
- Antibiotics.
- Physiotherapy.
- Bronchoscopy.

**Introduction**

Any small object that can get through the trachea or large bronchi, such as a seed, a peanut or an eraser from the top of a pencil, can lodge in the lower airway. If the object is too small to cause life-threatening choking it will enter the lower respiratory tract and cause subacute respiratory symptoms after an initial coughing bout.

**Diagnosis**

There may be a clear history from the parent or child of an episode of coughing or choking, followed by difficulty in breathing.
- On examination of the child’s chest, look to see whether there is less chest expansion on one side when breathing in.
- Feel the trachea. It may be pushed away from the midline by air trapping on the side affected by the foreign body.
- This may also be seen on a chest X-ray if available (see Figure 5.2.C.1), ideally an expiratory and inspiratory film.

An inhaled foreign body in a young child can go down the right or left side. In older children and adults, a foreign body on the right side is more common. There may be a harsh wheezing noise heard on the side of the chest where the foreign body has lodged.

**Treatment**

Air may be trapped in the lungs beyond the point where the foreign body has lodged, or this part of the lung may become infected. Give the child antibiotics. Chloramphenicol, 25 mg/kg every eight hours, is a good first choice, but add flucloxacillin or cloxacillin 25 mg/kg six hourly if there is a suspicion of or proven infection with Staphylococcus aureus. If there is evidence of severe pneumonia use the antibiotic combination in Section 5.3.A for severe pneumonia. Removal of a foreign body is a specialised procedure that must be carried out using a bronchoscope. Treat the infection until the child can be transferred to a hospital where this procedure can be performed. Some gentle physiotherapy may help, but take care not to dislodge the foreign body, as this will cause infection and obstruction in another part of the lung.

If the foreign body is not removed there will be subsequent bronchiectasis and recurrent chest infections (see Section 5.3.B).

For the management of choking, see Section 1.12.