Chris Carter is a 22-year-old man who has been brought into accident and emergency by his girlfriend. He is unable to speak because of shortness of breath which came on suddenly 2 days ago. His observations are:
- Respiratory rate 30/min
- Pulse 120 beats/min
- Blood pressure 110/70 mmHg
- Temperature 36.7°C
- Oxygen saturations 92% on room air
- Glasgow Coma Score 15

What should you do first?
In an emergency always start by checking airway, breathing and circulation (ABC). On observation, Mr Carter has a patent airway, is breathing and has an adequate cardiac output.

What other assessment can you make from his initial observations?
Mr Carter is tachycardic, probably as part of a stress response to his acute illness, but is maintaining an adequate blood pressure. He is in respiratory distress but managing to raise his respiratory rate to maintain oxygen saturations at 92%. He is not compromised from a neurological point of view as he has a normal Glasgow Coma Score.

What are the priorities for his management?
In an emergency situation it is vital that you take measures to save life and minimize potential disability even before you make a full assessment (Box 24, p. 36). Mr Carter is potentially at risk of cell injury and death from his hypoxia, which will have greatest impact on his brain and his heart. Immediate measures for Mr Carter should therefore include:
- High concentration oxygen therapy, 15L through a mask with a reservoir bag
- Insertion of an intravenous line to secure access for drug and fluid delivery
- Continuous monitoring:
  - oxygen saturation
  - cardiac rhythm
  - pulse
  - blood pressure
    He then needs more detailed assessment to identify and treat the underlying cause of his hypoxia.

What is your differential diagnosis for his acute shortness of breath?
As he is a young man the most likely diagnoses are:
- Acute asthma attack
- Pneumothorax
- Inhaled foreign body
- Allergic reaction (anaphylaxis)
- Lung trauma

How would you assess him to distinguish between these causes?
Although Mr Carter is unable to speak he is conscious and his girlfriend is with him. You should therefore briefly (1–2 min) establish whether he has a past history of asthma, allergy or lung disease and ask about trauma or foreign body inhalation. He should then be examined quickly to look for clinical signs that could point to an underlying diagnosis.

Mr Carter has a past history of asthma but no known allergies. There is no history of trauma or foreign body inhalation. On examination he is holding the sides of the trolley, leaning forward and gasping for breath. Heart sounds are faint but normal and there are no signs of cardiac failure. On respiratory examination his trachea is midline, expansion is equal on both sides but appears reduced, percussion is resonant and he has widespread expiratory polyphonic wheeze throughout both lung fields.
Do these new findings help you to make a diagnosis?
Symmetrical findings on chest examination (Table 1, p. 28) and expiratory wheeze in a patient with a past history of asthma are most likely to be caused by an acute exacerbation of asthma. Anaphylaxis and large airway obstruction by an inhaled foreign body can also cause wheeze, but lack of relevant history makes these diagnoses less likely than asthma.

What does his posture signify?
Patients in respiratory distress may grip the sides of their hospital trolley to fix their upper limb girdle. This allows them to use accessory muscles, including their pectoral muscles, to support inspiration.

What treatment should you give him immediately?
He should be treated as an acute exacerbation of asthma with immediate $\beta_2$-agonists for bronchodilatation and steroids to reduce airway inflammation.

Mr Carter is commenced on 5 mg salbutamol, nebulized using high flow oxygen and given 200 mg hydrocortisone intravenously.

What is the pathology underlying an asthma attack?
The underlying pathology in asthma is airway inflammation, which leads to mucosal swelling, increased secretion of mucus into the airway lumen and spasm of the smooth muscle of the airway wall. The net effect of these processes is to narrow the airway lumen, making it more difficult for the patient to breathe.

How do bronchodilators help?
These relax smooth muscle spasm and open up the airways, making it easier to breathe and improving oxygenation.

How is salbutamol nebulized?
A liquid preparation of salbutamol is put into a chamber of a nebulizer mask (Fig. 30). A gas (usually oxygen or air) is bubbled through the liquid and this vaporizes the drug into small droplets that can be inhaled into the airways. Patients with asthma should receive salbutamol nebulized with high flow oxygen to prevent them from becoming hypoxic during nebulization. Antimuscarinics (ipratropium) and steroids (budesonide) can also be given by nebulizer.

Why is the nebulizer used instead of his normal inhaler?
A nebulizer allows delivery of high doses of $\beta_2$-agonists (i.e. 2.5–5 mg salbutamol over a few minutes compared to 100 $\mu$g salbutamol per single puff of an inhaler). It is also easier for a patient with acute asthma to inhale nebulized drug passively as they breathe, rather than to try to generate the active and coordinated deep breaths required to take an inhaler. However, if a nebulizer is not available high dose $\beta_2$-agonists can be delivered using 4–6 puffs of the inhaler through a volumatic device (Fig. 29, p. 54) taken every 10–20 min.

How quickly should the salbutamol act?
Bronchodilatation should commence immediately with rapid improvement of symptoms. Nebulizers should be repeated every 15–30 min in patients with acute exacerbations of asthma.

How do corticosteroids help?
These are anti-inflammatory and reduce mucosal oedema and secretions. Corticosteroids are crucial in asthma as...
they treat the underlying inflammation and the patient is unlikely to recover without steroids.

KEY POINT

Asthma is an inflammatory condition and steroids are crucial for the treatment of the underlying pathology.

How quickly do you expect the steroids to act?
Corticosteroids exert most of their actions by binding to receptors and altering gene transcription. This process can take some time and corticosteroids are said not to have any effect for at least half an hour after the drug is given. However, studies have shown that the earlier corticosteroids are given in an asthma attack the better the outcome. The first dose of corticosteroids is usually given intravenously. This may be helpful in breathless patients who have difficulty swallowing and makes sure the patient receives the drug. However, oral steroids are just as effective in acute asthma as intravenous steroids.

Which investigations would you perform next (and why)?
- Peak expiratory flow rate (PEFR) to determine severity of asthma exacerbation
- Arterial blood gas to assess pH and PaCO₂ levels
- Chest X-ray to exclude other causes of breathlessness such as pneumothorax and underlying consolidation
- Full blood count and C-reactive protein (CRP) to look for evidence of infection
- Electrocardiogram (ECG) – to exclude cardiac disease as a cause or consequence of his condition

Initial investigation results are as follows:

<table>
<thead>
<tr>
<th>Investigation</th>
<th>Value</th>
<th>Normal range</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEFR</td>
<td>210 L/min</td>
<td>(Predicted 590 L/min)</td>
</tr>
<tr>
<td>Chest X-ray</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haemoglobin</td>
<td>14 g/dL</td>
<td>(12.5–17 g/dL)</td>
</tr>
<tr>
<td>White cells</td>
<td>12 × 10⁹/L</td>
<td>(4.0–11.0 × 10⁹/L)</td>
</tr>
<tr>
<td>Platelets</td>
<td>220 × 10⁹/L</td>
<td>(120–400 × 10⁹/L)</td>
</tr>
<tr>
<td>CRP</td>
<td>2 mg/L</td>
<td>(&lt;4 mg/L)</td>
</tr>
<tr>
<td>ECG</td>
<td>Sinus tachycardia</td>
<td></td>
</tr>
</tbody>
</table>

How do you interpret these results?
- His peak flow is 35% predicted, which is a feature of acute severe asthma (Box 31, p. 52)

How do you interpret his arterial blood gases?
- PaO₂ is low, indicating reduction of alveolar ventilation secondary to airflow obstruction. He is hypoxic but is not in respiratory failure, which is defined as PaO₂ <8 kPa
- PaCO₂ is low, indicating increased ventilation to compensate for hypoxia
- pH is raised (alkalosis). When PaCO₂ is reduced [1], this drives the Henderson–Hasselbach equation to the right [2], reducing hydrogen ion concentration [3] and

**KEY POINT**

Asthma is an inflammatory condition and steroids are crucial for the treatment of the underlying pathology.
Causing an alkalosis. As the respiratory problem is the primary abnormality, this is called a respiratory alkalosis.

\[
\begin{align*}
2 & \quad H^+ + HCO_3^- \rightleftharpoons H_2CO_3 \rightleftharpoons H_2O + CO_2 \\
1 & \quad \text{\textdollar} \\
3 & \quad \text{\textdollar}
\end{align*}
\]

How do you decide how severe his asthma attack is?
Mr Carter meets the criteria for a severe asthma attack (Box 31, p. 52). His peak flow is <50% predicted (35%), he has a respiratory rate of >25/min (30/min), is tachycardic (120 beats/min) and is unable to complete full sentences. He does not have any features of life-threatening asthma. It is important to make this assessment as this determines how and where he should be treated. Patients with severe attacks should usually be admitted to hospital for intensive therapy. Patients with life-threatening or near-fatal asthma will need intensive care monitoring.

After Mr Carter has received three 5 mg salbutamol nebulizers and 200 mg hydrocortisone he is reviewed. His observations now are:
- Respiratory rate 32/min
- Pulse 132 beats/min
- Blood pressure 124/82 mmHg
- Oxygen saturations 96% on high inhaled oxygen concentrations
- PEFR 170 L/min

How do you assess his progress?
Mr Carter has shown no signs of improvement on treatment. He remains tachycardic and tachypnoeic. If anything his asthma has deteriorated as his PEFR has fallen from 210 L/min (35% predicted) to 170 L/min (28% predicted) and his exacerbation is now classified as life-threatening (Box 31, p. 52). His increasing tachycardia could be a side-effect of salbutamol.

As he has not responded to initial treatment, what would you do next?
He needs additional bronchodilator treatment and referral to intensive care should be considered. He should continue with repeated nebulized salbutamol 2.5–5 mg every 15–30 min or continuously if possible. Other bronchodilators can be added to this treatment.

**Nebulized ipratropium bromide** (Box 41)
This should be given at the dose of 0.5 mg every 4–6 h and should produce significantly greater bronchodilatation than salbutamol alone. It is only used in acute severe or life-threatening asthma or patients who are not responding to β₂-agonists.

**Intravenous magnesium sulphate**
A single infusion of 1.2–2 g should be given over 20 min. Clinical trials have shown an improvement in PEFR and FEV₁ measurements in patients with acute severe asthma exacerbations treated with intravenous magnesium sulphate compared to placebo (Box 42).

Other options include the use of intravenous β₂-agonists or intravenous theophylline. However, there is less evidence to support the use of these treatments.
Mr Carter receives nebulized 0.5 mg ipratropium and intravenous 2 g magnesium sulphate and continues with nebulized salbutamol. He remains tachypnoeic and his blood gases are repeated on high oxygen concentrations:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Normal range</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.36</td>
<td>(7.35–7.45)</td>
</tr>
<tr>
<td>PaO₂</td>
<td>11.7 kPa</td>
<td>(10–13.1 kPa)</td>
</tr>
<tr>
<td>PaCO₂</td>
<td>6.3 kPa</td>
<td>(4.9–6.1 kPa)</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>26 mmol/L</td>
<td>(22–28 mmol/L)</td>
</tr>
</tbody>
</table>

**How have his blood gases changed?**
The most concerning change is an increase in PaCO₂ levels and fall in pH. At first sight his PaO₂ appears normal, but in fact he is requiring high inspired oxygen concentrations to maintain oxygenation.

**What is the significance of the new findings?**
A rising PaCO₂ now puts him into the category of near-fatalf asthma. He requires urgent intensive care input with possible ventilatory support.

**What might have caused this deterioration?**
- Mr Carter may be tiring with decreased respiratory effort leading to a PaCO₂ rise
- Patients with asthma can develop a secondary pneumothorax during exacerbation and this should always be considered if there is a sudden deterioration or failure to improve

Mr Carter is transferred to the intensive care unit for monitoring, treatment and consideration of invasive ventilation. A chest X-ray shows no evidence of pneumothorax. His condition is optimized with continuous nebulized salbutamol and intravenous theophylline. Over the next 30 min there is a gradual improvement in Mr Carter’s condition until he is able to say a few words. He is considered not to require invasive ventilation. After 48 h his condition has improved sufficiently for him to continue his recovery on a general medical ward.

**How should his asthma be monitored on the general ward?**
Ongoing assessment is important to evaluate response to treatment and recovery. Observations should include respiratory rate and O₂ saturations.

**Peak flow chart**
Peak expiratory flow rate should be measured morning and evening, before and after nebulizers. During an asthma attack PEFR will be reduced, lower in the morning than in the evening and increased by nebulizer treatment (bronchodilator reversibility). A rise in peak flow to normal values with disappearance of morning dipping and reduction in bronchodilator reversibility indicates recovery.

**As his asthma improves, how should his treatment be modified?**

**Corticosteroids**
- British Thoracic Society guidelines state that patients with acute asthma should receive 40–50 mg oral prednisolone for at least 5 days or until recovery
He should commence inhaled steroids as soon as possible during admission. The main reason for this is to ensure that he is taking inhaled steroids on discharge to form part of his chronic asthma management plan to prevent further exacerbations. Patients who have had an exacerbation in the past 2 years requiring steroids or nebulized bronchodilator should be taking inhaled steroids as per the stepped asthma guidelines (see Case 3).

**Bronchodilators**
He should have nebulized bronchodilators until:
- His symptoms have resolved
- PEFR morning dipping has decreased to less than 20% of PEFR

Bronchodilators should then be switched to inhaled therapy.

**Suggested treatment regime on discharge**
A reasonable approach to treatment on discharge after an asthma exacerbation would be to give patients:
- A steroid inhaler at standard or high dose twice daily
- A long-acting $\beta_2$-agonist twice daily
- A short-acting $\beta_2$-agonist inhaler initially to use regularly (e.g. 4 times per day) and then to use when needed (p.r.n.)

Patients with asthma will thus leave hospital following an exacerbation on step 3 or 4 treatment (depending on inhaled steroid dose) of the asthma guidelines, with a view to stepping down treatment in outpatients when their asthma is stable.

**When is it safe to discharge Mr Carter from hospital?**
A reasonable approach is to allow patients to go home when:
- They are able to mobilize around the ward without shortness of breath
- They are not breathless or troubled by severe cough at night
- They have been stable for 24 h after switching from nebulized to inhaled bronchodilators
- There is no significant morning dipping ($<20\%$ of maximum) on PEFR chart and values have risen to $>75\%$ best or predicted values

1 Mr Carter’s peak flow chart is shown in Fig. 32.
How do you interpret this chart?
Initially, Mr Carter’s PEFR recordings are low, there is morning dipping and a pre-nebulizer reading is lower than the post-nebulizer reading. As he improves, his peak flow rises and morning dipping is reduced. By day 4, his morning dipping is less than 20% and his peak flow is 530 L/min (90% predicted best of 590 L/min). He is therefore switched to inhaled therapy and remains stable on this for a further 24 h, at which stage he is ready for discharge.

What should be done before he leaves hospital to reduce the chance of further exacerbations?
Mr Carter should receive education about his asthma and how to prevent further attacks, preferably from a specialist respiratory nurse or other trained staff. This education should include:
- Correct inhaler technique
- Making and recording home peak flow measurements
- Explanation of the purpose of different inhalers prescribed and the importance of taking them
- Self-management plan, including advice about early management of future exacerbations and when to seek help

Some of this will need to be carried out or continued as an outpatient and so an appointment should be given for follow-up in the respiratory clinic.

Why is education and follow-up so important?
Asthma can kill. There are around 1400 deaths annually in the UK from asthma according to national statistics. Factors associated with death include:
- Severe asthma
- Inadequate treatment or monitoring of asthma
- Adverse behavioural or psychosocial features leading to inadequate asthma management

Most severe acute asthma exacerbations develop over 6 h or more, so there should be time for patients to receive appropriate help. Prompt action at the onset of an exacerbation may prevent hospitalization and death. Education and follow-up can be used to advise patients when and how to seek timely help.

Education should also address asthma triggers (Box 29, p. 47) and measures that can be taken to avoid exacerbations. Patients with severe asthma or recent hospital admission should be advised to have vaccination against influenza.

Reference
Further advice and information for patients with asthma is provided by Asthma UK and can be found at www.asthma.org.uk/index.html

Outcome. Mr Carter is seen by the respiratory nurse specialist. His inhaler technique is corrected and he receives a self-management plan and a number to contact if he has questions. He is discharged taking:
- 40 mg prednisolone orally for 5 more days
- 250 mg beclometasone per dose, 2 puffs twice daily
- 25 µg salmeterol per dose, 2 puffs twice daily
- Salbutamol metered dose inhaler (100 µg per dose), 2 puffs as required

In outpatients 4 weeks later his symptoms have resolved. His PEFR is 580 L/min. His treatment is gradually stepped down over several months until he is maintained on 200 µg beclometasone twice daily and salbutamol p.r.n.
Asthma kills around 1400 people annually in the UK. Recognition and prompt treatment of asthma exacerbations is essential to reduce asthma-related deaths. At presentation, clinical features and basic investigations should be used to determine the severity of the asthma exacerbation. Corticosteroids must be given to patients with asthma exacerbations as soon as possible to treat underlying inflammation. 2.5–5 mg nebulized salbutamol every 15–30 min should be used to improve symptoms and respiratory function in severe asthma while the anti-inflammatory effects of corticosteroids are taking effect. If patients respond poorly to nebulized salbutamol other bronchodilators recommended for use are: nebulized ipratropium, intravenous magnesium. Intravenous theophylline or salbutamol can also be tried by respiratory clinicians.

Failure to respond or deterioration in a patient with acute asthma can be caused by: intractable disease, tiring/exhaustion, secondary pneumothorax. Intensive care should be considered early for patients with life-threatening or near-fatal asthma. Recovery from asthma exacerbation can be judged by improvement in symptoms and peak flow recordings. Patients can usually be discharged safely when they have minimal symptoms and PEFR >75% best or predicted with <20% morning dipping after 24 h on inhalers. Prior to discharge, patients should receive education from trained staff to reduce the risk of further exacerbations. Patients should be followed-up by a respiratory specialist after hospitalization for an asthma exacerbation.