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GUIDELINE FOR THE MANAGEMENT OF ACUTE SEVERE ASTHMA IN ADULTS: 2012 UPDATE

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Guideline for the management of acute asthma in adults: 2013 update

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Acute asthma attacks (asthma exacerbations) are increasing episodes of shortness of breath, cough, wheezing or chest tightness associated with a decrease in airflow that can be quantified and monitored by measurement of lung function (peak expiratory flow (PEF) or forced expiratory volume in the 1st second) and requiring emergency room treatment or admission to hospital for acute asthma and/or systemic glucocorticosteroids for management. The goals of treatment are to relieve hypoxaemia and airflow obstruction as quickly as possible, restore lung function, and provide a suitable plan to avoid relapse. Severe exacerbations are potentially life-threatening and their treatment requires baseline assessment of severity, close monitoring, and frequent reassessment using objective measures of lung function (PEF) and oxygen saturation. Patients at high risk of asthma-related death require particular attention. First-line therapy consists of oxygen supplementation, repeated administration of inhaled short-acting bronchodilators (beta-2-agonists and ipratropium bromide), and early systemic glucocorticosteroids. Intravenous magnesium sulphate and aminophylline are second- and third-line treatment strategies, respectively, for poorly responding patients. Intensive care is indicated for severe asthma that is not responsive to first-line treatment. Antibiotics are only indicated when there are definite features of bacterial infection. Factors that precipitated the acute asthma episode should be identified and preventive measures implemented. Acute asthma is preventable with optimal control of chronic asthma.

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1. Introduction

The prevalence of asthma is increasing worldwide,[1] and surveys indicate that the majority of patients in developed and developing countries do not receive optimal care and are therefore not well controlled.[1] The aim of this guideline is to promote an optimal standard of management of acute asthma in order to facilitate rapid recovery and transition to chronic care. It is intended as a companion to the management of chronic persistent asthma, as adherence to the latter plays a pivotal role in reducing acute asthma morbidity and mortality.

2. Methodology

The South African Thoracic Society first published a guideline for the management of acute asthma in 1994. This 2013 update of the guideline was prompted by the need for:

- incorporation of advances in the pharmacological treatment of acute severe asthma
- early recognition and objective assessment of acute severe asthma
- optimal management and rapid transition to chronic care
- prevention of acute attacks
- harmonisation with international guidelines (e.g. Global Initiative for Asthma (GINA)).

The guideline was developed following meetings with a working group of pulmonologists and primary care/family medicine practitioners constituted by the South African Thoracic Society and chaired by Professor U G Lalloo. The initial meeting was held with the working group on 2 - 3 July 2005. Subsequently the editorial board was convened and met on several further occasions to develop and finalise this guideline document. The meetings were sponsored by the National Asthma Education Program (NAEP) of the South African Thoracic Society. This was made possible through unrestricted educational grants to the NAEP from the SA Thoracic Society, Altana Madaus (now Nycomed), AstraZeneca, Boehringer Ingelheim, GlaxoSmithKline and MSD.

3. Evidence

The strategies recommended in this guideline are classified according to the evidence categories in Table 1 and denoted as **evidence A, B, C** and **D**.

4. Acute asthma symptoms, acute asthma and exacerbations

The cardinal symptoms of asthma are cough, tightness of chest, wheeze and shortness of breath. There is remarkable variation in the perception of asthma symptoms and therefore concern for patients who have a blunted perception of the severity of their asthma symptoms.[1]

Acute symptoms are episodic and are managed by self-medication with a reliever medication (inhalation of beta-2 (β_2)-agonists). The frequent use of reliever medication indicates suboptimal control and demands attention to controller treatment.[1]

Asthma exacerbations, also referred to as **acute asthma** or **asthma attacks**, result from frequent and progressive asthma symptoms and require early recognition to prevent morbidity and mortality. In some patients acute exacerbations may be of abrupt onset and progress rapidly to respiratory failure and death. An asthma exacerbation may be defined for practical purposes as a progressive (usually) or abrupt worsening in asthma symptoms, with increased use of bronchodilators (rescue medication) with progressively decreasing response and/or a decrease in pulmonary function as measured by PEF or spirometry.[1,2] The term **status asthmaticus** is used less often and refers to an asthma exacerbation that is severe and continuous.

The features of acute asthma are due to widespread narrowing of the airways. The pathophysiology of airway narrowing is complex, and smooth-muscle constriction, hypersecretion of mucus and mucus plugging of small airways, oedema of the airway wall with infiltration with inflammatory cells (e.g. neutrophils and eosinophils), and disruption of the airway epithelium are all involved.[1]

Key points

- Acute asthma attacks (asthma exacerbations) are episodes of increased shortness of breath, coughing, wheezing or chest tightness associated with a decrease in airflow that can be quantified and monitored by measurement of lung function (peak expiratory flow (PEF) or forced expiratory volume in the 1st second (FEV_1)) and require emergency room treatment or admission to hospital for acute asthma, and/or systemic glucocorticosteroids (CS) for management.
- The goals of treatment are to relieve hypoxaemia and airflow obstruction as quickly as possible, restore lung function, and provide a suitable plan to avoid relapse.
- Severe exacerbations are potentially life-threatening, and their treatment requires baseline assessment of severity, close monitoring, and frequent reassessment using objective measures of lung function (PEF) and oxygen saturation.
- Patients at high risk of asthma-related death require particular attention.
- First-line therapy consists of oxygen supplementation, repeated administration of inhaled short-acting bronchodilators (beta-2-agonists and ipratropium bromide), and early systemic CS.
- The factors that precipitated the attack should be identified and attempts made to prevent future attacks.

Table 1. Categories of evidence for management strategies in asthma (reproduced with permission from Global Initiative for Asthma 2006)

Evidence category	Sources of evidence
A	Randomised controlled trials: Rich body of data
B	Randomised controlled trials: Limited body of data
C	Non-randomised trials: Observational studies
D	Panel consensus judgement

5. Management of acute asthma

The management of acute asthma is summarised in Fig. 1. The key steps are:

5.1 Initial assessment and classification of severity

A brief history and physical examination should be conducted immediately the patient presents and **at the same time as treatment is initiated**.[1] A detailed history may follow once the patient is stable and should include the duration and severity of symptoms, exercise tolerance, sleep disturbance, all current medications (including devices and doses prescribed and taken, time of onset and cause of the present attack, possible triggers, and presence of high-risk factors (see below)). The examination should assess the

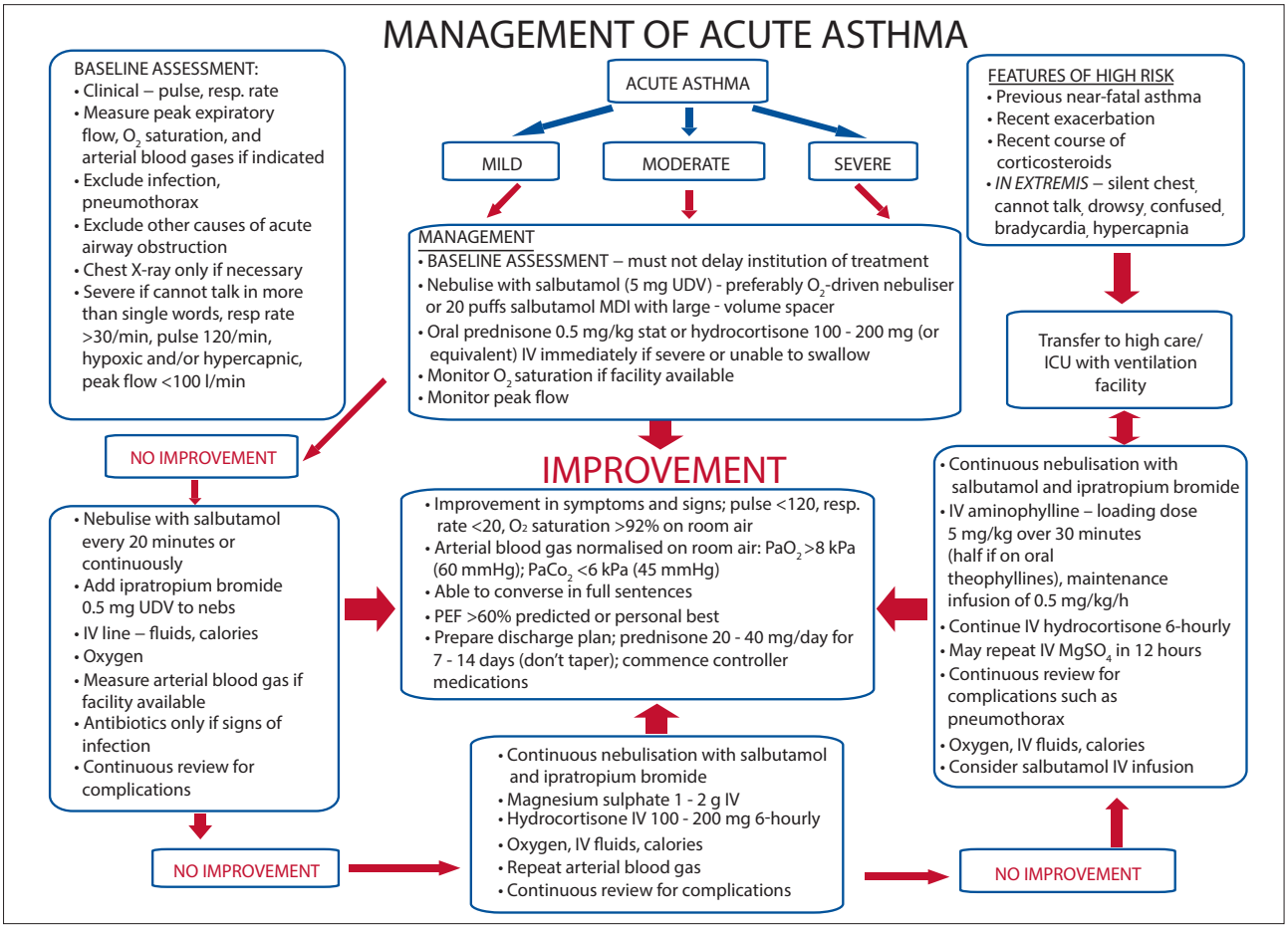

Fig. 1. Algorithm for the management of acute asthma.

presence of any complications (e.g. pneumonia, lobar collapse or atelectasis, pneumothorax and pneumomediastinum). Objective functional assessments such as baseline PEF or FEV_1 and arterial oxygen saturation (SpO_2) measurements (by pulse oximetry) before starting treatment should be routine[1,3-7] (**evidence C**). PEF measurement is preferred in emergency units, hospital wards, primary care clinics and general practitioner surgeries because it is widely available, simple, inexpensive, portable and safe. A baseline PEF measurement should be made before treatment is initiated[1] (see Appendix I, 'How to measure peak expiratory flow (PEF)'), but may not be possible in patients with severe respiratory distress. Arterial blood gas measurements are required if the SpO_2 is <92% or the attack is responding poorly to treatment.[6,7] The measurement should be made while the patient is on supplemental oxygen. A chest radiograph is not routine but should be done if a complication or other disease (e.g. tuberculosis, lung cancer) is suspected or if there is poor response to treatment, but its acquisition must not compromise ongoing monitoring and treatment.[8]

Acute asthma may be conveniently classified as mild, moderate or severe (life-threatening) based on symptoms, signs, and lung function and laboratory data. Table 2 summarises the features of acute asthma and criteria used to classify the severity of acute asthma.

5.2 Identification of patients at high risk

In addition to patients who are classified as having acute severe asthma, patients must also be considered as at high risk if they have any of the features listed in Table 3.[9,10] Such patients are at risk of rapid deterioration.

5.3 Treatment

The goals of treating acute asthma are to:

- prevent worsening
- relieve airway obstruction (rapidly improves symptoms)
- treat hypoxia
- restore lung function to normal or previous best
- prevent relapse.

5.3.1 Bronchodilators

There are several classes of bronchodilators for acute asthma, each with a different mode of action and used sequentially depending on the response to treatment. They are presented in order of importance with a view to a stepwise approach to treatment.

5.3.1.1 β_2-agonists

Short-acting inhaled β_2-agonists (SABAs), e.g. **salbutamol** and **fenoterol**, are the cornerstone of bronchodilator treatment for acute asthma exacerbations[1,11,12] (**evidence A**). They act by stimulating β_2 receptors in the airways. When the patient responds well to SABAs (usually 2 or 3 doses given by nebulisation or metered dose inhalation) there is no need for any other bronchodilator treatment for acute asthma.[1] The following are the key properties of SABAs:

- They are administered by inhalation, most commonly by nebulisation in acute asthma.
- They rapidly improve airway obstruction.

Table 2. Severity of acute asthma (exacerbations)*

	Mild	Moderate	Severe	Respiratory arrest imminent
Breathless	Walking	Talking	At rest	
	Can lie down	Prefer sitting	Hunched forward	
Talks in	Sentences	Phrases	Words	
Alertness	May be agitated	Usually agitated	Usually agitated	Drowsy or confused
Respiratory rate	Increased	Increased	Often >30/min	Silent chest
Accessory muscles and suprasternal retractions	Usually not	Usually	Usually	Paradoxical thoraco-abdominal movement
Wheeze	Moderate	Loud	Usually loud	Absence of wheeze
Pulse rate (/min)	<100	100 - 120	>120	Bradycardia
Pulsus paradoxus	Absent <10 mmHg	May be present <20 mmHg	20 - 40 mmHg	Absence implies respiratory muscle fatigue
PEF after initial bronchodilator, % predicted or % personal best	>80%	Approx. 60 - 80%	<60% of predicted or personal best (<100 l/min adults) OR Response lasts <2 hours	
PaO_2 (breathing room air)	Normal	>60 mmHg (8 kPa)	<60 mmHg (8 kPa)	
	Test not usually necessary		cyanosis	
AND/OR				
$PaCO_2$	<45 mmHg (6 kPa)	<45 mmHg (6 kPa)	>45 mmHg (6 kPa)	
SaO_2 % (on room air)	>95%	91 - 95%	<90%	

*The presence of several parameters, but not necessarily all, indicates the general classification of the exacerbation.
PaO_2 = arterial blood oxygen partial pressure; $PaCO_2$ = arterial blood carbon dioxide partial pressure; SaO_2% = arterial oxygen saturation.

Table 3. High-risk patients

Current use of or recent withdrawal from systemic corticosteroids
Recent emergency care and/or hospitalisation for asthma
Frequent emergency care attendance
Previous resuscitation and/or intensive care unit admission for severe attack
Previous sudden severe attack/s with few or no warning features despite regular treatment (so-called 'brittle asthma')
Recent over-reliance on and excessive use of β2-agonists
History of non-adherence with asthma medication
History of psychosocial problems

- They may be repeated as frequently as necessary depending on the patient's response: clinical improvement and improvement in peak flow to >60% predicted or >60% of previous best. Some experts propose 75%. β2-agonists may be administered continuously (every 20 minutes) in acute asthma.[13,14]
- In severe acute asthma, it is recommended that whenever possible they should be administered using an oxygen-driven nebuliser.
- They are relatively safe even in high doses when administered by nebulisation.
- They may be given by intravenous infusion in exceptional circumstances when nebulisation is not possible or is considered unreliable.[15]

How to administer?

SABAs are administered repeatedly as the best way of achieving rapid reversal of airflow obstruction (Table 4)[11,12] (**evidence A**). If the attack is severe or life-threatening, delivery via an oxygen-driven nebuliser is mandatory. In mild to moderate exacerbations a metered dose inhaler (MDI) together with a large-volume spacer (LVS) produces at least an equivalent improvement in lung function and is more cost-effective.[16] If using an MDI plus an LVS, put 2 puffs (100 µg/puff) into the LVS and advise the patient to take several deep breaths from the spacer, repeating the procedure for up to 20 puffs over 20 minutes for 1 hour. For nebulisation administer 5 mg salbutamol or 1 mg fenoterol, available in premixed unit dose vials (UDVs), initially. If a rapid response is not obtained, repeat the nebulisation every 20 minutes (continuously) for 1 hour. After the first hour, the frequency will depend on the severity of the attack and the response to initial treatment. No additional bronchodilator medication is necessary if the SABA produces a complete response (PEF returns to >60% of predicted or personal best) and the response is sustained for several hours. Consider continuous nebulisation (3 UDVs per hour) in patients with severe acute asthma (PEF or FEV_1 <50% of previous best or predicted) and those poorly responsive to initial intermittent β2-agonist therapy[13,14] (**evidence A**).

Intravenous salbutamol is rarely used. It is given as an initial dose of 0.5 mg intravenously slowly, followed by a maintenance dose of 3 - 20 µg/min (5 mg diluted in 500 ml dextrose water or normal saline). It should be continued until there is sustained improvement (ideally <24 hours). Serum potassium and lactate should be monitored.

5.3.1.2 Anticholinergics

Inhaled ipratropium bromide is the only anticholinergic agent for the treatment of acute asthma. It achieves bronchodilation by a vagal pathway through inhibition of muscarinic receptors. Its bronchodilator effect in asthma is inferior to that of SABAs. The key properties of ipratropium bromide are:

- It is administered by inhalation only – most commonly by nebulisation or with an MDI with an LVS.
- There is no evidence that it provides significant additional bronchodilator effect to optimal doses of SABAs in mild to moderate acute asthma. It is therefore reserved as a second-line bronchodilator treatment for severe acute asthma.
- Combination with a SABA produces better bronchodilation than either drug alone[17,18] (**evidence B**) and is associated with lower hospitalisation rates in severe acute asthma[17-19] (**evidence A**). It is usually added to SABA nebulisation solution when there is poor or inadequate response to repeated doses of inhaled SABAs.

How to administer?

Ipratropium bromide may be administered in combination with a SABA every 20 minutes via a nebuliser at a dose of 0.5 mg in UDVs. It may also be administered via an MDI and LVS (20 µg/puff, up to 20 puffs).

5.3.1.3 Magnesium sulphate

Magnesium sulphate has recently been demonstrated to have bronchodilator effects and is of value (reducing hospital admission) in severe acute asthma when other bronchodilators fail[20-22] (**evidence A**). It probably works by inhibiting smooth-muscle contraction, decreasing histamine release from mast cells, and inhibiting acetylcholine release. The properties of magnesium sulphate are:

- It is mainly used intravenously (can be used by nebulisation with SABAs but with much less benefit[22-24]).
- It is not recommended routinely in acute asthma, but is of value in severe acute asthma (patients with FEV_1 <25%) and those not responsive to other bronchodilators.
- It is generally safe, but may be associated with side-effects of flushing, sweating, hypotension, nausea, muscle weakness and central nervous system depression.

How to administer?

Intravenous magnesium sulphate may be given as a 1 - 2 g infusion over 20 minutes. It should be given as a single-dose infusion and may be repeated once, but not sooner than 12 hours.

Nebulised magnesium sulphate should be administered at a dose of 135 - 1 150 mg together with a SABA, but this is far less effective than intravenous administration.[23,24]

5.3.1.4 Theophylline

Intravenous **aminophylline** is the only theophylline recommended in acute asthma. It is a theophylline with ethylenediamine to render it water-soluble. It is thought to act by phosphodiesterase inhibition and non-selective adenosine receptor antagonism. Selective phosphodiesterase inhibitors such as roflumilast are not registered for use in acute asthma. The properties of aminophylline are:

- It has a very narrow therapeutic range, and toxicity is common (cardiac arrhythmias, nausea and vomiting, convulsions, hypotension and coma).[25]
- It is not routinely given in acute asthma, as no synergism has been demonstrated. Only recommended when there is no response to SABAs, ipratropium bromide and magnesium sulphate (i.e. severe refractory asthma).

How to administer?

A loading dose of 5 mg/kg is infused over 30 minutes (withhold or give only half the dose to patients already on oral theophylline), followed by a maintenance infusion of 0.5 mg/kg/h (approximately 1 000 mg/24 h). This should be increased by one-third (0.9 mg/kg/h) in smokers and patients taking phenytoin and decreased by one-third in the elderly and those with congestive cardiac failure or liver disease, or taking a macrolide, ciprofloxacin or cimetidine. Blood levels should be monitored daily and the dose adjusted accordingly.

5.3.1.5 Others

Adrenaline has been replaced by the β2-agonists and is rarely indicated for acute asthma attacks. It may, however, be used if no intravenous access is immediately available and the patient is moribund. Subcutaneous adrenaline (0.3 ml of 1/1 000 solution, repeated every 20 minutes if no response) has been successful and side-effects are not significant even when given intravenously under emergency circumstances. It has also been administered via an endotracheal tube if a patient is unable to take inhaled medication and/or there is no intravenous access.[1] It may also be used if there is associated anaphylaxis or angio-oedema. Special care must be taken in the elderly and those with or at risk of cardiovascular disease.

5.3.2 Glucocorticosteroids

Glucocorticosteroids are recommended routinely for the treatment of acute asthma (**evidence A**).[26,27] They are the most important anti-inflammatory agents in asthma. The key properties of CS are:

- They prevent relapse.[26,27]
- Onset of action is within hours of administration, and the first dose should be given orally or intravenously immediately treatment for acute asthma is commenced.
- Oral CS are usually as effective and work as quickly as those given intravenously, and are preferred because they are cheaper and less invasive.[28,29]
- CS need to be continued for 7 - 14 days.[30]
- CS have been shown to be effective when administered by MDI or nebulisation in acute asthma,[31,32] but the inhaled route is not cost-effective or as reliable as systemic administration in acute asthma. There is insufficient evidence that the inhaled route can replace systemic CS in acute asthma.[33,34]
- They result in resolution of the airway inflammation that contributes significantly to the airway obstruction in acute asthma and is not reversed with bronchodilators such as β2-agonists, anticholinergics, magnesium sulphate and theophylline.

How to administer?

CS are usually given in the form of oral prednisone (0.5 - 1 mg/kg or equivalent per day, usually 30 - 50 mg daily) in all patients with acute asthma attacks [26,27] (**evidence A**) and continued for 7 - 14 days.[30] There is no advantage in using a higher dose [26,27] (**evidence B**) or in tapering the dose when administered for this duration[35] (**evidence B**). Intravenous CS (hydrocortisone 100 - 200 mg or equivalent, 6-hourly) can be used if the patient is vomiting or unable to take oral medication. Highly potent CS such as dexamethasone and betamethasone are not recommended in acute asthma.

Standard-dose inhaled CS should be started during the admission and continued on discharge as part of chronic therapy[31-34,36-38] **(evidence A).**

5.3.3 Oxygen

Supplemental oxygen must be administered whenever possible in patients with moderate to severe acute asthma. Also, nebulised bronchodilators should whenever possible be delivered by oxygen-driven nebulisers. Most patients with moderate to severe acute asthma have hypoxia that is readily corrected by supplemental oxygen.

How to administer?

Oxygen is generally administered by facemask and response monitored with pulse oximetry to maintain an O_2 saturation over 92%[1,6,39] (**evidence C**). Lack of pulse oximetry should not prevent oxygen being administered. There is usually no need to administer more than 40% oxygen. The flow rates are determined by the recommendations on the specific facemasks. If inhaled bronchodilator therapy is given by nebulisers, they should preferably be driven by oxygen at a flow rate of at least 6 l/min to prevent hypoxaemia[6,40] (**evidence A**).

5.3.4 Miscellaneous treatments

Antibiotics are not routinely indicated in acute asthma and should only be given if there is definite evidence of infection such as fever, purulent sputum and clinical and/or radiological signs of pneumonia.[41,42] Note that yellowish sputum is frequent in acute asthma and is due to the high eosinophil content and not a sign of infection on its own.

Intravenous fluids are administered in acute severe asthma based on the clinical setting, taking into account maintenance and replacement requirements and the need for calorie intake in patients unable to take oral fluids. There are no formal studies of routine fluid administration in acute asthma.

Heliox is a mixture of helium and oxygen. It has the advantage of reducing airway resistance and has been used in desperate circumstances in non-responsive severe acute asthma.[43-45] It is not available in most centres.

5.3.5 Treatments for which there is no evidence of benefit and/or that should be avoided

Leukotriene modifiers are not currently recommended in acute asthma.[1,46]

Antihistamines have no role in acute asthma.

Mucolytics, given either systemically or by nebulisation, are contraindicated as they may worsen cough and bronchospasm and only serve to complicate the treatment regimen.

Sedatives should be strictly avoided during asthma attacks because of their respiratory depressant effect. Their use in non-intubated patients has been associated with asthma deaths.[42,47,48]

Physiotherapy may provoke bronchospasm and worsen the attack. It is only indicated if there is lobar collapse that persists despite initial bronchodilator and CS therapy.[42]

5.3.6 Stepwise treatment of acute asthma

The stepwise treatment of acute asthma is set out in Table 4.

5.4 Assessment of response to treatment

Measurements of pulse rate, respiratory rate, PEF or FEV_1 and arterial oxygen saturation should be made at 15 - 30-minute intervals until a clear response to treatment is achieved.[3-5,42,49] Measurement of the change in PEF in response to initial therapy is one of the best ways to assess response to treatment for acute asthma.[1,42,49] Early response to treatment (PEF at 30 minutes) is the most important predictor of outcome and need for hospitalisation.[42,49] Criteria for endotracheal intubation and/or intensive care unit (ICU) admission are listed in Table 5. ICU management of acute asthma is described below. Once a satisfactory response is obtained the patient may:

- be discharged on a course of oral prednisone for 7 - 14 days together with controller medication
- continue to receive bronchodilator treatment in the emergency room, ward, high-care unit or ICU at a frequency of 4 - 8-hourly based on the attending physician's discretion. Ongoing monitoring of baseline parameters such as clinical status, PEF, SpO_2, arterial blood gas, etc. is at the attending physician's discretion.

Table 4. Stepwise treatment of acute asthma

A. First line	Oxygen: by 40% facemask or nasal cannulas to keep saturation >92%
	SABAs: via nebuliser (5 mg salbutamol or 1 mg fenoterol in premixed UDVs) every 20 minutes until a satisfactory response; or via MDI plus LVS (10 - 20 puffs (100 µg/puff) over 20 minutes, taking several deep breaths from spacer after every 2 puffs)
	Systemic corticosteroids: prednisone 0.5 - 1 mg/kg orally stat and daily; or hydrocortisone (or equivalent) 100 - 200 mg intravenously 6-hourly in severe acute asthma or if unable to swallow or vomiting
	These treatments are usually administered concurrently to achieve the most rapid resolution of the attack and prevention of relapse
B. Second line	Ipratropium bromide: 4-hourly via nebuliser (0.5 mg in premixed UDVs, usually with a SABA) every 20 minutes until a satisfactory response; or via MDI plus LVS (up to 20 puffs (20 µg/puff) over 20 minutes, taking several deep breaths from spacer after every 2 puffs)
C. Third line	Intravenous magnesium sulphate: 1 - 2 g infusion over 20 minutes
	Intravenous aminophylline: loading dose of 5 mg/kg infusion over 30 minutes (administer half the dose if on maintenance theophyllines), then maintenance infusion of 0.5 mg/kg/h
D. Fourth line	Intravenous salbutamol: 0.25 mg IV slowly, then maintenance infusion of 3 - 20 µg/min

SABAs = short-acting inhaled β2-agonists; UDVs = unit dose vials; MDI = metered dose inhaler; LVS = large-volume spacer.

5.5 Mechanical ventilation

- Intubation should be performed with a large-diameter tube by the most experienced person available. The induction agent is a matter of personal preference. Benzodiazepines cause respiratory depression, so the initial attempt must be rapidly successful. Etomidate (0.2 - 0.4 mg/kg), propofol (2 - 2.5 mg/kg) and ketamine (1 - 2 mg/kg) are other options. The latter has sedative, analgesic and anaesthetic properties without respiratory depression, but increases bronchial secretions and causes hallucinations. Succinylcholine remains the agent of choice for acute paralysis despite histamine release.[50] Volume modes ensure delivery of a tidal volume (TV) that exceeds physiological dead space (usually 5 - 6 ml/kg ideal body weight or 250 - 300 ml).[51]
- Set the peak pressure alarm such that the desired volume is actually delivered. The pressure required to deliver an adequate TV may be quite high when airflow resistance is very high. Considerable expertise is required to manage ventilation in these patients.
- Auto-PEEP (positive end-expiratory pressure). Auto-PEEP causes hyperinflation and haemodynamic compromise and should be minimised. Auto-PEEP is influenced by respiratory rate, TV, and the inspiratory-to-expiratory time ratio and inspiratory flow rates. Ventilator graphics make the monitoring of PEEP much simpler.[52]
- Start with a respiratory rate of 8 - 12 breaths per minute with no or minimal external PEEP.
- Permissive hypercapnia, a higher CO_2 than normal, is acceptable provided the pH is >7.2. If the pH is less than this, increase the respiratory rate cautiously as this may increase auto-PEEP.
- Short-duration paralysis may sometimes be necessary. Non-depolarising agents such as vecuronium bromide, rocuronium bromide, cisatracurium besilate and pancuronium bromide may all be used and do not induce bronchospasm. Atracurium besilate and mivacurium chloride cause dose-dependent histamine release, but it is not certain whether this causes clinical deterioration. Stop paralysis as soon as possible, as the combination of steroid and neuromuscular blocking agents is particularly likely to cause critical illness myopathy.[53]
- When the patient improves, convert to pressure support modes. A trial of external PEEP is warranted as this may decrease work in spontaneously breathing patients.[54] Non-invasive ventilation remains controversial and is not routinely recommended.[55]

Criteria for endotracheal intubation/ICU admission are listed in Table 5, and suggested criteria for discharge from the emergency unit in Table 6.[49,56-59] If the pretreatment FEV_1 or PEF is <25% predicted or personal best, or the post-treatment FEV_1 or PEF <40% predicted or personal best, admission is usually required.[1,59]

Once admitted for poor response, the optimal duration of hospital stay is unclear. There is often major bed pressure to discharge patients too early, but this increases the risk of early relapse. Readmission may occur in the next 2 - 3 months,[57] particularly if the diurnal variation in PEF is >20%, and a course of oral CS and optimisation of long-term controller treatment are essential to reduce relapse.[58]

Table 5. Criteria for endotracheal intubation/ICU admission

1. Signs of imminent respiratory arrest:
   a. Cyanosis
   b. Exhaustion/drowsiness
   c. Confusion/poor co-operation
   d. Silent chest
   e. Bradycardia
   f. Rising $PaCO_2$
   g. Persistent acidosis
   h. Respiratory arrest
2. Poor response to initial therapy at clinic/hospital (PEF deteriorates)

$PaCO_2$ = arterial blood carbon dioxide partial pressure; PEF = peak expiratory flow.

Table 6. Criteria for discharge from the emergency unit

1. Adequate response to initial therapy within 1 - 2 hours (as evidenced by pulse, respiratory rate, wheeze/breath sounds, oxygen saturation)
2. PEF improves to >60% predicted (some experts propose 75%)
3. No prolonged symptoms before current emergency unit visit
4. No recurrence after recent exacerbation
5. Absence of high-risk factors
6. Good social factors (adequate access to medical care, medicines and transport)

PEF = peak expiratory flow.

5.6 Prevention of relapses

The factors that precipitated the attack should be identified and attempts made to avoid them.[60-63]

5.7 Discharge plan

- Provide a 7 - 14-day course of oral CS (20 - 40 mg daily of prednisone or equivalent). No tapering required if used for this duration.
- Instruct the patient to use their inhaled bronchodilator (SABA) as required for both symptomatic and objective improvement (PEF if available) until they are stable and return to their baseline.
- Review the patient's use of controller therapy during the exacerbation. Patients should commence or continue inhaled CS (frequently in the form of a combination inhaler with long-acting β2-agonists). If the patient was already on inhaled CS, careful attention should be paid to reviewing the dose. Consider providing a short course of oral CS to be taken in the event of subsequent exacerbations for frequent exacerbators.
- The patient's inhaler technique and use of a peak flow meter to monitor therapy at home should be reviewed.
- A follow-up appointment with the patient's usual primary care provider or an asthma specialist should be made within 2 weeks of discharge to ensure that treatment is continued to achieve control. Ideally, patients discharged from the emergency unit should be referred to specialist care as they do better than those returned to routine care.[64]
- The patient's response to the attack should be evaluated. A written asthma action plan should be reviewed or provided. Hospitalised patients are more receptive to information and advice about their illness.[63] Healthcare providers should take the opportunity to review patient understanding of the causes of asthma attacks, trigger avoidance (including smoking cessation), the purpose and correct use of treatment, and the action to take in response to worsening symptoms or peak flow values[60-63] (**evidence A**).

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Appendix I. How to measure peak expiratory flow (PEF)

As airways narrow, the PEF rate falls. The PEF is usually measured using the mini-Wright peak flow meter (Fig. 2). Careful instruction is required to measure PEF reliably because its measurement is effort-dependent.[1] The maximum rate of flow of air that the patient can forcibly exhale starting from full inhalation, expressed in litres per minute, is measured. It should be explained in simple terms ('take a deep breath in, and then blow out as hard and fast as possible into the meter, like blowing out the candles on a cake'). However, it is much easier and more effective to show a patient how to use a peak flow meter than to explain it to them in words only. PEF should be recorded as the best of three forced expiratory blows from total lung capacity in a standing or sitting position, with a maximum pause of 2 seconds before blowing.[2] The subject does not have to exhale completely.

PEF expressed as a percentage of the patient's previous best value is most useful clinically, but in the absence of a known previous best value, it should be expressed as a percentage of predicted.[1,2] PEF depends on the patient's age, sex and height. The normal reference values sourced from the Nunn and Gregg nomogram are recommended for the calculation of 'percentage predicted' PEF values[2,3] (Fig. 3).

Fig. 2. The mini-Wright peak flow meter.

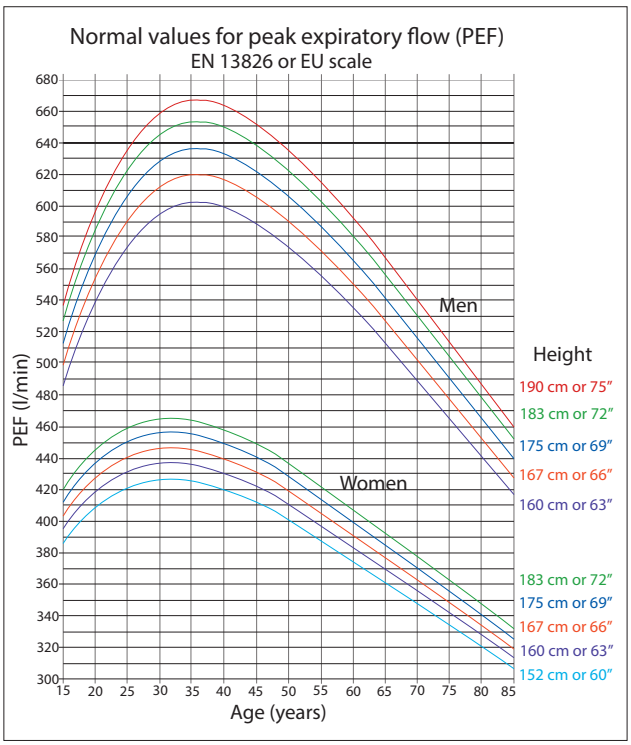

Fig. 3. The Nunn and Gregg nomogram for determining predicted peak expiratory flow rates in adolescents and adults.