

Mechanical ventilation in the emergency department

Intubation and mechanical ventilation are often needed in emergency treatment.

A ENGELBRECHT, MB ChB, MMed (Fam Med), Dip PEC, DA

Head, Emergency Medicine Unit, University of Pretoria Medical School and Pretoria Academic Hospital

Andreas Engelbrecht is Head of the Emergency Unit at Pretoria Academic Hospital. He has a special interest in airway management and in the provision of critical care in the emergency department.

G R TINTINGER, MB ChB, MMed (Int)

Head, Medical ICU, Department of Internal Medicine, Pretoria Academic Hospital and University of Pretoria

Greg Tintinger has a keen interest in critical care medicine and pulmonology.

An increasing number of critically ill patients need to be managed in emergency departments worldwide. Numerous theories have attempted to explain the growing number of critically ill patients presenting to emergency departments, including the complex medical problems of an expanding elderly population in countries such as the USA.¹ The situation in South Africa is exacerbated by HIV and trauma epidemics.

Critically ill patients who require intubation and mechanical ventilation often need to be treated for extended periods in emergency departments. It is therefore no longer acceptable to apply a single strategy of ventilation for all such patients. This is especially true with increasing awareness of the complications of mechanical ventilation, such as barotrauma, volutrauma and biotrauma.

In this new and challenging environment the emergency physician is expected to be familiar with the mechanical ventilators in his/her unit and to be able to select an appropriate strategy for each critically ill patient requiring mechanical ventilation. In this article, key aspects are addressed that highlight the essential skills required to ventilate patients safely and appropriately (Table I).

Indications for mechanical ventilation (Table II)

It is important to remember that the indications for endotracheal intubation and mechanical ventilation in the emergency department are not necessarily the same. Some patients are intubated simply for airway protection, while others are intubated owing to respiratory failure. Where the indication for intubation is simply to protect the airway, patients may be allowed to breathe spontaneously with supplemental oxygen via a T-tube. Indications for intubation and ventilation can be divided into 2 categories: (i) ventilatory failure, in which the neuromuscular mechanisms of breathing cannot maintain adequate ventilation in the presence of normal lungs; and (ii) oxygenation failure, which usually occurs with disease of the airway or lung parenchyma.

Modes of ventilation

Positive pressure breaths may be delivered to the airways of patients receiving mechanical ventilation in two ways, namely mandatory (ventilator breathes for the patient and performs all the work of breathing), or assisted (patient-triggered breath with support from the ventilator).

Furthermore, each breath is preset to deliver either a target tidal volume or inspiratory pressure (depending on the mode of ventilation). The most commonly used mode of ventilation is that which is volume targeted (i.e. a preset tidal volume is delivered at a predetermined frequency and flow rate). Alternatively, a pressure-targeted mode may be selected (i.e. preset inspiratory pressure delivered to the airways).² These modes, with examples of each, are summarised in Fig. 1.

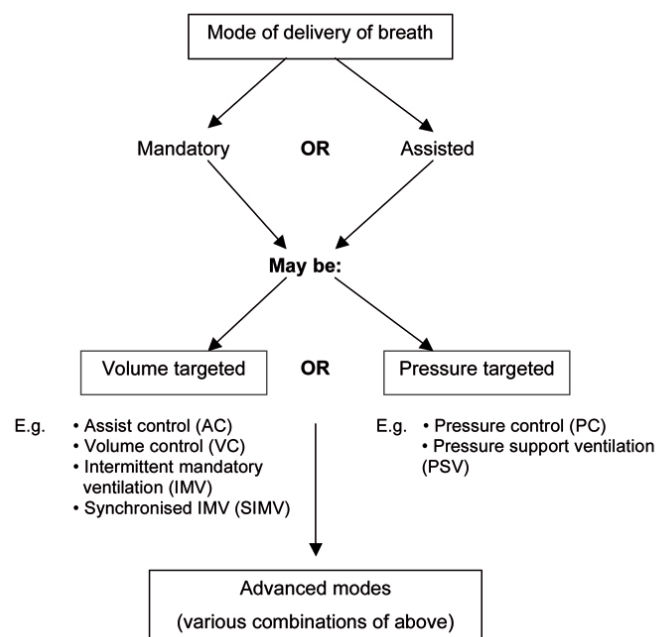


Fig. 1. Modes of ventilation.

Table I. Key questions to ask before and during the mechanical ventilation of a critically ill patient in the emergency department

- What are the indications for mechanical ventilation?
- Which mode of ventilation should I select?
- What are the standard settings for ventilated patients?
- What are the goals of ventilation?
- Which strategy of ventilation is appropriate for the specific clinical condition?
- When should I use positive end-expiratory pressure (PEEP)?
- How should I respond when a ventilator alarm is triggered?
- What are potential complications of mechanical ventilation?
- How should mechanical ventilation be discontinued?

Table II. Indications for mechanical ventilation**Failure to breathe (normal lungs)**

- CNS pathology, e.g. severe head injury or decreased cerebral perfusion due to shock
- Drugs and poisons, e.g. heroin overdose
- Neuromuscular disease, e.g. myasthenia gravis or Guillain Barré syndrome

Poor gas exchange (sick lungs)

- Localised or diffuse lung infiltrates, e.g. acute respiratory distress syndrome (ARDS), severe cardiogenic pulmonary oedema, pneumonia and aspiration
- Severe airflow obstruction, e.g. asthma/chronic obstructive pulmonary disease (COPD)

It is vital to be familiar with the basic modes of ventilation that can be used in the emergency unit. Rather be expert in fewer ventilation modes and with the ventilators commonly used in your unit, as this will be sufficient for most circumstances encountered.

Standard settings

A sound working knowledge of the mechanical ventilators used in your hospital permits ventilator parameters to be set confidently without undue delay.³ The basic parameters to be set differ slightly according to the mode of ventilation, but usually include the parameters for volume and pressure-targeted modes set out in Table III.

Note: Peak airway pressures are dependent on lung and chest wall compliance as well as airway resistance and may vary from patient to patient in volume-driven modes. Similarly, the tidal volume delivered to

the patient is not guaranteed when using pressure-driven modes.

Goals of ventilation

The primary goal of mechanical ventilation is adequate oxygenation. This should be confirmed by serial arterial blood gas determinations of P_aO_2 and saturation after initiation of mechanical ventilation.

The traditional approach has been to aim for normoxia, normocarbida and a normal pH.⁴ In patients with primary lung pathology, aiming for these goals can lead to high airway pressures (barotrauma), large tidal volumes (volutrauma) and high inspired oxygen concentrations (oxygen toxicity). Therefore, for patients with ARDS permissive hypercapnoea ($P_aCO_2 \geq 50$ cm H₂O) and moderate acidosis (pH 7.25 - 7.40) may be allowed in order to protect the lungs. In patients without underlying lung disease the traditional approach can be followed.

Table III. Parameters to be set (suggested values for patients with normal lungs)

Volume-targeted mode

- Oxygen concentration (F_iO_2) (< 60%)
- Rate/min (10 - 20)
- Tidal volume (8 - 10 ml/kg)
- Inspiratory flow rate (50 - 70 l/min) (determines inspiratory time)
- PEEP (3 - 5 cm H₂O)
- Alarm limits

Pressure-targeted mode

- F_iO_2 (< 60%)
- Rate/min (10 - 20)
- Inspiratory pressure (10 - 30 cm H₂O)
- Inspiratory:expiratory ratio (I:E = 1:3)
- PEEP (3 - 5 cm H₂O)
- Alarm limits

The second important goal of ventilation is to reduce the work of breathing of the patient to prevent fatigue of the respiratory muscles. This will lower the oxygen demand on the respiratory muscles and conserve oxygen for vital organs.

The third goal is that of a comfortable patient on the ventilator. This is achieved by selecting the correct mode of ventilation and by providing sufficient sedation and analgesia.

Goals of mechanical ventilation

- Oxygenation (most important).
- Protect lungs from barotrauma and volutrauma.
- Reduce work of breathing of patient.
- Patient must be comfortable on ventilator.
- Correct acid-base balance.

Selection of a ventilation strategy

The ventilation strategy refers to the ventilator settings appropriate for the specific condition of the patient.⁵ Three groups of patients can be identified based on clinical and radiological findings.

Firstly, those with normal lungs in whom standard settings may be used.

Secondly, those with lung infiltrates due to pneumonia, ARDS, aspiration or cardiogenic pulmonary oedema and accumulation of fluid in the alveoli, which decrease lung compliance. This leads to hypoxia and high airway pressures when standard settings are used. In these patients application of PEEP is the most effective way to recruit collapsed alveoli and improve oxygenation. Other methods include inverse ratio ventilation where the I:E ratio is increased to 1:1, or prone positioning which may be difficult to perform in the emergency department. Smaller tidal volumes should be selected to maintain plateau pressures below 35 cm H₂O and peak airway pressures ≤ 45 cm H₂O.⁶

Thirdly, for patients with severe airflow obstruction due to asthma and COPD, the set rate should be lowered to allow longer expiratory times and I:E ratios of 1:3 or 1:4. Volumes should be reduced with higher inspiratory flows, which allow a greater portion of the ventilatory cycle to be spent in expiration. Because intrinsic PEEP may be increased in asthma and COPD, the use of applied (extrinsic) PEEP should be limited (< 5 cm H₂O) (see the algorithm for selection of a ventilation strategy).⁷

Algorithm for selection of a ventilation strategy:

Always ascertain that the patient is not hypoxic by giving *enough* oxygen

(F_{iO_2} 90 – 100%) in early phases

(F_{iO_2} can be reduced to non-toxic levels when patient is stable)



Determine the *reasons* for intubation and ventilation

- Airway protection (e.g. head injury)
- Respiratory failure (check arterial blood gas)



History

Clinical examination

Chest X-ray (CXR)

Ventilatory failure

Oxygenation failure

- Drug overdose
- History of asthma/COPD
- Bronchospasm/silent chest

- Trauma
- ARDS
- Pneumonia / pulmonary oedema
- Crackles or bronchial breathing may be audible
- CXR – significant areas of opacification or haemothorax/pneumothorax

CXR – no significant opacification

CXR – no significant opacification, but may show hyperinflation or pneumothorax

Follow standard ventilation protocol (Table III)

Follow ventilation protocol for airflow obstruction (Table IV)

Follow ventilation protocol for lung infiltrates (Table IV)

Intercostal drain

Table IV. Ventilation strategies for lung infiltrates and airflow obstruction

	Lung infiltrates (ARDS, pneumonia) Fig. 2	Airflow obstruction (asthma, COPD) Fig. 3
X-ray image	Fig. 2	Fig. 3
Ventilator settings		
F_{iO_2}	100% until condition is stabilised, then < 60%	100% until condition is stabilised, then < 60%
Tidal volume	6 - 8 ml/kg to keep airway pressures low	6 - 8 ml/kg to minimise exhaled volumes
Respiratory rate	16 - 24/min	6 - 10/min
PEEP	8 - 15 cm H ₂ O	0 - 4 cm H ₂ O
I:E ratio	1:2, consider inverse ratio 1:1 only if $SO_2 < 90\%$ despite adequate PEEP	1:3 to 1:4 to allow longer time for expiration

Setting positive end-expiratory pressure (PEEP)

PEEP refers to a level of positive pressure maintained during the expiratory phase of ventilation, which facilitates recruitment of non-functioning regions of the lung.

PEEP is applied to minimise alveolar collapse (atelectasis) associated with conditions such as ARDS, aspiration, multilobar pneumonia and cardiogenic pulmonary oedema. With high levels of PEEP, patients should be closely monitored for adverse effects such as hypotension resulting from diminished cardiac preload and cardiac output or barotrauma.

Ventilator alarms

Ventilator alarms are used to alert nurses and clinicians that a set limit (pressure, volume, rate, F_{iO_2}) has been reached, which may have deleterious consequences for the patient. The following steps should be taken when a ventilator alarm sounds.

1. Check patient's oxygenation and peripheral saturation.
2. Make sure that the ventilator circuit is intact, with the endotracheal tube in the correct position.
3. Confirm breath sounds in both lungs.
4. Determine the reason for the alarm alert and treat according to the underlying cause, e.g. high peak airway pressures may be caused by airway secretions, biting on tube, kinked tubing, bronchospasm or pneumothorax.
5. Chest X-ray or arterial blood gas may be needed as part of the assessment.
6. Never ignore an alarm alert – it is usually for a good reason.

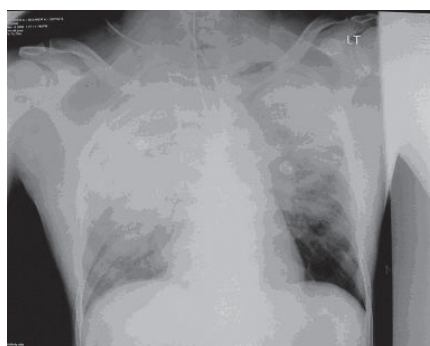


Fig. 2. Bilateral infiltrates typical of ARDS.



Fig. 3. Hyperinflated lungs typical of COPD.

Complications of mechanical ventilation

- Complications of endotracheal intubation, e.g. endotracheal tube in oesophagus or right main bronchus or tracheal tear.
- Pneumothorax and tension pneumothorax (Fig. 4).
- Oxygen toxicity.
- Lung injury due to volutrauma, barotrauma and atelectotrauma.
- Hyperventilation and hypoventilation.



Fig. 4. This patient developed a pneumothorax during mechanical ventilation.

- Infection.
- Hypotension.
- Acute myocardial infarction.
- Stress ulceration.

Discontinuation of mechanical ventilation (weaning)

Mechanical ventilation can usually be discontinued when the following criteria are met:

- good oxygenation ($P_aO_2 > 70$ mmHg, saturation $\geq 92\%$) on F_{iO_2} of 40% and PEEP = 5 cm H₂O
- the condition necessitating ventilation has been reversed (e.g. patient regains consciousness)
- patient is haemodynamically stable without significant cardiac arrhythmias or impending organ failure
- patient's level of consciousness allows spontaneous breathing and adequate protection of airway (without excessive sedation).

Numerous methods for the discontinuation of ventilation have been advocated (e.g. IMV, pressure support) with few significant advantages of any particular one of these being found during randomised controlled trials. The principle behind each one is to allow patients to increase their own work of breathing while reducing the contribution of the ventilator without unnecessary delay. Therefore, as soon as a patient meets the above criteria, measure the rapid shallow breathing index (RSBI) (respiratory rate/tidal volume) after spontaneous breathing for 1 min, and if RSBI < 105 institute a spontaneous breathing trial (SBT). The SBT should last about 30 - 90 min with careful monitoring of peripheral saturation, respiratory rate, pulse rate, blood pressure, mental status and pattern of breathing. The SBT should be terminated if patients develop signs of respiratory muscle fatigue (respiratory

Mechanical ventilation

rate > 30/min or abdominal paradox), marked anxiety or significant alterations in vital signs from baseline values. Extubation can proceed after completion of a successful SBT.

References

1. Goldstein RS. Management of the critically ill patient in the emergency department: focus on safety issues. *Critical Care Clin* 2005; 21: 81-89.
2. Gali B, Deepi GG. Positive pressure mechanical ventilation. *Emerg Med Clin N Am* 2003; 21: 453-473.
3. Orebaugh SI. Initiation of mechanical ventilation in the emergency department. *Am J Emerg Med* 1996; 14: 59-69.
4. Bhangwanjee S. Theory and practical issues in ventilatory support of the trauma victim. *Trauma and Emergency Medicine* 1999; 16: 35-39.
5. Spritzer CJ. Unravelling the mysteries of mechanical ventilation: a helpful step-by-step guide. *J Emerg Nurs* 2003; 29: 29-36.
6. Ware LB, Matthay MA. Medical progress: the acute respiratory distress syndrome. *NEJM* 2000; 342: 1334-1349.
7. Phipps P, Garrard CS. The pulmonary physician in critical care: Acute severe asthma in the intensive care unit. *Thorax* 2003; 58: 81-88.

In a nutshell

- An increasing number of patients need to be managed in emergency departments worldwide.
- The situation in South Africa is exacerbated by HIV and trauma epidemics.
- Mechanical ventilation is an important facet of critical care provided in emergency departments.
- Indications for mechanical ventilation include failure to breathe in spite of normal lungs and poor gas exchange due to sick lungs.
- Each physician should be familiar with the basic modes of ventilation that can be used in emergency units.
- The goals of ventilation include oxygenation, lung protection, reduced work of breathing, acid-base balance and that the patient should be comfortable on the ventilator.
- Separate ventilation strategies exist for patients with normal lungs, patients with outflow obstruction such as COPD and asthma, and patients with lung infiltrates such as ARDS and pneumonia.
- Never ignore a ventilator alarm sounding – it exists for a good reason.
- Mechanical ventilation can be discontinued when the patient is stable and the condition necessitating ventilation has been reversed.

single suture *Persistent otitis media and development*

A new study, published in the *New England Journal of Medicine*, suggests that persistent otitis media in young children does not cause developmental problems later in life. In the trial, which started in 1991, researchers followed a cohort of 241 children with otitis media. They found that early treatment with tympanostomy tubes made no difference to cognitive, academic or social development of children up to the age of 11 when compared with 6 months of watchful waiting. The final results were consistent with previous findings from the same children at the ages of 3, 4 and 6 years. The trial started when there were serious concerns in the USA – but no real evidence – that persistent middle-ear effusion could cause irreversible damage to a child's ability to learn. Placement of tympanostomy tubes became the second most common operation in the USA, after neonatal circumcision.

Paradise JL, et al. *N Engl J M* 2007; 356: 300-302.