Appendices


A.1.1 Introduction

Guidelines for cardiopulmonary resuscitation (CPR) are published every 5 years by the International Liaison Committee on Resuscitation (ILCOR). The committee includes representatives from the American Heart Association (AHA), the European Resuscitation Council (ERC), the Heart and Stroke Foundation of Canada (HSFC), the Australian and New Zealand Committee on Resuscitation (ANZCOR), the Resuscitation Council of Southern Africa (RCSA), the Inter-American Heart Foundation (IAHF), and the Resuscitation Council of Asia (RCA).

Since 2000, researchers from the ILCOR member councils have evaluated resuscitation science in 5-yearly cycles. The most recent International Consensus Conference was held in Dallas in February 2015 and the published conclusions and recommendations from this process form the basis of the ILCOR Guidelines which were published simultaneously in the journals Circulation and Resuscitation.

The guidelines are constructed from systematic reviews of all scientific and clinical papers concerning all aspects of CPR which had been published during the previous 5 years. The reviewing process is carried out by international experts working according to strict guidelines about how the evidence is assessed and the exact language in the way the guidelines are expressed. The basis of the review exercise is to base all CPR upon sound scientific evidence. There are many components to cardiopulmonary resuscitation and not all these are reviewed during each 5 year cycle.

There is always great interest in the publication of new ILCOR guidelines from all those who may be involved in CPR. These include paramedical and medical personnel as well as public first responder training, fire, police and other non-medical services. ILCOR emphasises that the published guidelines are not necessarily...
binding. This means that they can be open to interpretation by medically – trained personnel who can make their own clinical decisions according to the circumstances. However, for non – medical personnel the guidelines are regarded as rules which are followed rigidly in training programmes.

The 2015 ERC Guidelines, published in the journal Resuscitation state specifically that ‘they do not define the only way that resuscitation can be delivered; they merely represent a widely accepted view of how resuscitation should be undertaken both safely and effectively. The publication of new and revised treatment recommendations does not imply that current clinical care is either unsafe or ineffective.’

A.1.2 Publication of the Guidelines

Up to 2010 the published guidelines in Resuscitation and Circulation were almost identical but this has not been the case with the latest guidelines which were published in October 2015. The AHA guidelines are published in 15 parts which cover all aspects of adult and paediatric CPR. They are set out with the reference base and evidence ratings as before but the 2015 guidelines included a Master List of Recommendations which cover the year when the topic was last reviewed and current recommended advice. Not every topic relating to CPR is reviewed every 5 years and this table helps to clarify this point and emphasize that the recommendations from the previous guidelines are still valid, even if they have not been reviewed again as part of the current guidelines.

The ERC published guidelines do not make this clear, nor do they publish specific levels of evidence for recommendations as does the AHA. Consequently, for a topic like the use of portable automatic ventilators in CPR and post CPR care, the 2015 AHA guidelines give a clear recommendation for their use while the subject receives almost no attention in the ERC guidelines. This is markedly different from their 2010 guidelines which discussed ventilators in some detail. The AHA guidelines also make it clear that ventilation has not been reviewed in the past 5 years and that the 2010 guidelines are still valid.

A.1.3 The Basis of the Evidence

Assessment of ventilation in CPR from an evidence based – standpoint is made difficult by the relatively small numbers of published studies on the topic compared with many papers relating to the restoration and management of circulation and the management of airways. Thus recommendations for ventilation are based on a limited number of publications and therefore do not usually have a high evidence rating. Nevertheless, the 2015 ILCOR guidelines do contain clear
recommendations about ventilation based on what evidence is available and this paper summarises the current guidelines and their application, together with new recommendations for monitoring which are of importance to the use of ventilation devices.

A.1.3.1 Presentation of Evidence Levels and the Wording of the Guidelines

The 2015 AHA guidelines present the way that scientific evidence relating to resuscitation is analysed and the form of wording that should be used for recommendations. A synopsis of this process is found the annex to this paper. It will be seen in the guidelines that the words ‘it is reasonable to....’ appear frequently in relation to artificial ventilation. This choice of wording is highly arbitrary and, in the opinion of the author inappropriate for a subject that is embedded in modern medicine and has obvious proven value. To use the words ‘it is reasonable to use artificial ventilation....’ for the management of a child that has stopped breathing where artificial ventilation is essential and life – saving highlights the problem of the subjective system of wording chosen by AHA. The established life saving position of artificial ventilation, set out in the various chapters of this book show that it should be described as ‘highly desirable’ at the very least. Table 1 shows the basis of the AHA statements of evidence.

A.1.4 ERC and AHA 2015: The Main Changes from the 2010 Guidelines for Airway and Ventilation Management

Overall, there have been no substantial changes to fundamental CPR with the chest compression to ventilation ratio remaining at 30:2 for basic life support with an unprotected airway and 100 compressions per minute with ten ventilations per minute for protected airway. For rescue and bag valve ventilation the inspiratory time remains at 1 s.

A.1.4.1 Basic Adult Life Support

The ERC version of the guidelines lists the following key changes from the 2010 guidelines:

(i) CPR providers should perform chest compressions for all victims in cardiac arrest. CPR providers trained and able to perform rescue breaths should combine chest compressions and rescue breaths. Our confidence in the equivalence between chest compression-only and standard CPR is not sufficient to change current practice.
### Table 1 The AHA class of recommendations and level of evidence for the 2015 CPR guidelines

<table>
<thead>
<tr>
<th>CLASS (STRENGTH) OF RECOMMENDATION</th>
<th>LEVEL (QUALITY) OF EVIDENCE:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CLASS I (STRONG)</strong></td>
<td><strong>LEVEL A</strong></td>
</tr>
<tr>
<td>Suggested phrases for writing recommendations:</td>
<td>- High-quality evidence† from more than 1 RCTs</td>
</tr>
<tr>
<td>- Is recommended</td>
<td>- Meta-analyses of high-quality RCTs</td>
</tr>
<tr>
<td>- Should be performed/administered/other</td>
<td>- One or more RCTs corroborated by high-quality registry studies</td>
</tr>
<tr>
<td><strong>CLASS IIa (MODERATE)</strong></td>
<td><strong>LEVEL B-R</strong> (Randomized)</td>
</tr>
<tr>
<td>Suggested phrases for writing recommendations:</td>
<td>- Moderate-quality evidence† from 1 or more RCTs</td>
</tr>
<tr>
<td>- Can be useful/effective/beneficial</td>
<td>- Meta-analyses of moderate-quality RCTs</td>
</tr>
<tr>
<td><strong>CLASS IIb (WEAK)</strong></td>
<td><strong>LEVEL B-NR</strong> (Nonrandomized)</td>
</tr>
<tr>
<td>Suggested phrases for writing recommendations:</td>
<td>- Moderate-quality evidence† from 1 or more well-designed, well-executed randomized controlled trials, observational studies, or registry studies</td>
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<tr>
<td>- May/might be reasonable</td>
<td>- Meta-analyses of such studies</td>
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<tr>
<td>- May/might be considered</td>
<td>- Physiological or mechanistic studies in human subjects</td>
</tr>
<tr>
<td>- Usefulness/effectiveness is unknown/unclear/uncertain or not well established</td>
<td><strong>LEVEL C-1D</strong> (Limited Data)</td>
</tr>
<tr>
<td><strong>CLASS III: No Benefit (MODERATE)</strong></td>
<td><strong>LEVEL C-EO</strong> (Expert Opinion)</td>
</tr>
<tr>
<td>(Generally with class of A or B recommended)</td>
<td>Consensus of expert opinion based on clinical experience</td>
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<tr>
<td>Suggested phrases for writing recommendations:</td>
<td></td>
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<tr>
<td>- Is not recommended</td>
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<tr>
<td>- Is not indicated/useful/effective/beneficial</td>
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<tr>
<td>- Should not be performed/administered/other</td>
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<tr>
<td><strong>CLASS III: Harm (STRONG)</strong></td>
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<tr>
<td>(Generally with class of A or B recommended)</td>
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<tr>
<td>Suggested phrases for writing recommendations:</td>
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<tr>
<td>- Potentially harmful</td>
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<tr>
<td>- Causes harm</td>
<td></td>
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<tr>
<td>- Associated with excess morbidity/mortality</td>
<td></td>
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<tr>
<td>- Should not be performed/administered/other</td>
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(ii) High-quality CPR remains essential to improving outcomes. The guidelines on compression depth and rate have not changed. CPR providers should ensure chest compressions of adequate depth (at least 5 cm but no more than 6 cm) with a rate of 100–120 compressions min−1. After each compression allow the chest to recoil completely and minimise interruptions in compressions. When providing rescue breaths/ventilations spend approximately 1 s inflating the chest with sufficient volume to ensure the chest rises visibly. The ratio of chest compressions to ventilations remains at 30:2.
(iii) Do not interrupt chest compressions for more than 10s to provide ventilations.

The AHA guidelines list the following key changes from the 2010 BLS guidelines:

1. More data are available indicating that high-quality CPR improves survival from cardiac arrest.

   Components of high-quality CPR include:

   • Ensuring chest compressions of adequate rate
   • Ensuring chest compressions of adequate depth
   • Allowing full chest recoil between compressions
   • Minimizing interruptions in chest compressions
   • Avoiding excessive ventilation

Recommendations are made for a simultaneous, choreographed approach to performance of chest compressions, airway management, rescue breathing, rhythm detection, and shock delivery (if indicated) by an integrated team of highly trained rescuers in applicable settings.

2. It is reasonable for healthcare providers to provide chest compressions and ventilation for all adult patients in cardiac arrest, from either a cardiac or a noncardiac cause (Class IIb, LOE C-LD).

3. When the victim has an advanced airway in place during CPR, rescuers no longer deliver cycles of 30 compressions and two breaths (i.e., they no longer interrupt compressions to deliver 2 breaths). Instead, it may be reasonable for the provider to deliver one breath every 6 s (ten breaths per minute) while continuous chest compressions are being performed (Class IIb, LOE C-LD).

4. When the victim has an advanced airway in place during CPR, it may be reasonable for the provider to deliver one breath every 6 s (10 breaths per minute) while continuous chest compressions are being performed (Class IIb, LOE C-LD). This simple rate, rather than a range of breaths per minute, should be easier to learn, remember, and perform.

A.1.4.2 Adult Advanced Life Support

The evidence base for airway and ventilation management during cardiopulmonary resuscitation remains very limited. The following statement in the executive summary of the ERC version of the ILCOR guidelines summarizes the situation:

   The optimal strategy for managing the airway has yet to be determined. Several observational studies have challenged the premise that advanced airway interventions (tracheal intubation or supraglottic airways) improve outcomes. The ILCOR ALS Task Force has suggested using either an advanced airway (tracheal intubation or supraglottic airway (SGA)) or a bag-mask for airway management during CPR. This very broad recommendation is made because of the total absence of high quality data to indicate which airway strategy is best. In practice a combination of airway techniques will be used stepwise during a resuscitation attempt. The best airway, or combination of
Airway techniques will vary according to patient factors, the phase of the resuscitation attempt (during CPR, after ROSC), and the skills of rescuers. A stepwise approach to airway and ventilation management using a combination of techniques is therefore suggested.

AHA Key Changes for Airway – Ventilation

Significant New and Updated Recommendations: 2015

1. Based on new data, the recommendation for use of the maximal feasible inspired oxygen during CPR was strengthened. This recommendation applies only while CPR is ongoing and does not apply to care after return of spontaneous circulation (ROSC).

2. Continuous waveform capnography remained a Class I recommendation for confirming placement of an endotracheal tube. Ultrasound was added as an additional method for confirmation of endotracheal tube placement.

3. The AHA table of master recommendations for the use of portable ventilators during and after CPR states the following (based upon the analysis to 2010)

   1. Automatic Transport Ventilators

      In both out-of-hospital and in-hospital settings, automatic transport ventilators (ATVs) can be useful for ventilation of adult patients in non-cardiac arrest who have an advanced airway in place

      (Class IIb, LOE C), (not reviewed in 2015)

   2. Automatic Transport Ventilators

      During prolonged resuscitative efforts the use of an ATV (pneumatically powered and time- or pressure-cycled) may allow the EMS team to perform other tasks while providing adequate ventilation and oxygenation (Class IIb, LOE C). (not reviewed in 2015)

AHA Statements from the 2010 Guidelines

ATV can be useful in an out-of-hospital setting in patients with an airway in place and who are not in cardiac arrest

Very few studies have been published which evaluate the use of ATV during resuscitation

During prolonged resuscitation, the use of ATV (gas-powered, time or pressure cycled) may allow EMS teams to perform other tasks while providing adequate ventilation and oxygenation

ERC Guidance on Adult ALS Ventilation

The ERC 2015 guidelines for adult ALS do not make any mention of portable ventilators. From the information provided by the AHA guidelines this may be explained
by the fact that the topic has not been reviewed since 2010. However, unlike the AHA the ERC have not clarified this point.

The following statements concerning airway and ventilation management appear in the ERC version of the 2015 ILCOR guidelines:

Advanced Life Support providers should give artificial ventilation as soon as possible for any patient in whom spontaneous ventilation is inadequate or absent. Expired air ventilation (rescue breathing) is effective, but the rescuer’s expired oxygen concentration is only 16–17%, so it must be replaced as soon as possible by ventilation with oxygen-enriched air. The pocket resuscitation mask is similar to an anaesthetic facemask, and enables mouth-to-mask ventilation. It has a unidirectional valve, which directs the patient’s expired air away from the rescuer. The mask is transparent so that vomit or blood from the patient can be seen. Some masks have a connector for the addition of oxygen. When using masks without a connector, supplemental oxygen can be given by placing the tubing underneath one side and ensuring an adequate seal. Use a two-hand technique to maximise the seal with the patient’s face. High airway pressures can be generated if the tidal volume or inspiratory flow is excessive, predisposing to gastric inflation and subsequent risk of regurgitation and pulmonary aspiration.

The risk of gastric inflation is increased by:

- Malalignment of the head and neck, and an obstructed airway;
- An incompetent oesophageal sphincter (present in all patients with cardiac arrest);
- A high airway inflation pressure.

Conversely, if inspiratory flow is too low, inspiratory time will be prolonged and the time available to give chest compressions is reduced. Deliver each breath over approximately 1 s, giving a volume that corresponds to normal chest movement; this represents a compromise between giving an adequate volume, minimizing the risk of gastric inflation, and allowing adequate time for chest compressions. During CPR with an unprotected airway, give two ventilations after each sequence of 30 chest compressions. Inadvertent hyperventilation during CPR is common. While this increased intrathoracic pressure and peak airway pressures in a small case series in humans, a carefully controlled animal experiment revealed no adverse effects. We suggest a ventilation rate of 10 min−1 during continuous chest compressions with an advanced airway based on very limited evidence.

Self-inflating bag The self-inflating bag can be connected to a facemask, tracheal tube or supraglottic airway (SGA). Without supplementary oxygen, the self-inflating bag ventilates the patient’s lungs with ambient air (21% oxygen). The delivered oxygen concentration can be increased to about 85% by using a reservoir system and attaching oxygen at a flow 10 l min−1. Although a bag-mask enables ventilation with high concentrations of oxygen, its use by a single person requires considerable skill. When used with a face mask, it is often difficult to achieve a gas-tight seal between the mask and the patient’s face, and to maintain a patent airway with one hand while squeezing the bag with the other. Any significant leak will cause hypoventilation and, if the airway is not patent, gas may be forced into the stomach. This will reduce ventilation further and greatly increase the risk of regurgitation and aspiration. The two-person technique for bag-mask ventilation is preferable. Several recent observational studies and a meta-analysis have documented better outcomes with use of bag-mask ventilation compared with more advanced airways (SGA or tracheal tube). However, these observation studies are subject to significant bias caused by confounders such as advanced airways not being required in those patients who achieve ROSC and awaken early. Once a tracheal tube or a SGA has been inserted, ventilate the lungs at a rate of ten breaths min−1 and continue chest compressions without pausing during ventilations. The laryngeal seal achieved with a supraglottic airway (SGA) may not be good enough to prevent at least some gas leaking when inspiration coincides with chest compressions. Moderate gas leakage is acceptable, particularly as most of this gas will pass up through the patient’s mouth.
Waveform Capnography During Advanced Life Support (a New Topic) in the 2015 ERC and AHA Guidelines

Waveform capnography enables continuous real-time EtCO$_2$ to be monitored during CPR. During CPR, EtCO$_2$ values are low, reflecting the low cardiac output generated by chest compression. There is currently no evidence that use of waveform capnography during CPR improves patient outcomes, although the prevention of unrecognised oesophageal intubation is clearly beneficial. The role of waveform capnography during CPR includes:

- Ensuring tracheal tube placement in the trachea.
- Monitoring ventilation rate during CPR and avoiding hyperventilation.
- Monitoring the quality of chest compressions during CPR. EtCO$_2$ values are associated with compression depth and ventilation rate and a greater depth of chest compression will increase the value. Whether this can be used to guide care and improve outcome requires further study.
- Identifying ROSC during CPR. An increase in EtCO$_2$ during CPR may indicate ROSC and prevent unnecessary and potentially harmful dosing of adrenaline in a patient with ROSC. If ROSC is suspected during CPR withhold adrenaline. Give adrenaline if cardiac arrest is confirmed at the next rhythm check.
- Prognostication during CPR. Lower ETCO$_2$ values may indicate a poor prognosis and less chance of ROSC; however, we recommend that a specific EtCO$_2$ value at any time during CPR should not be used alone to stop CPR efforts. End-tidal CO$_2$ values should be considered only as part of a multi-modal approach to decision-making for prognostication during CPR.

ERC 2010 Guidelines for the Use of Portable Ventilators

In 2010 the ERC made the following comments about the use of portable ventilators in CPR which are still relevant in 2015 (See Deakin et al., *Resuscitation* 2010;81: 1305–1352)

1. Emphasis on avoiding high airway pressure (p1318)

   The difficulty of using the self – inflating bag by one person is acknowledged. When using a bag valve device a two person technique is preferable.

2. Automatic ventilators

   P 1319

   Very few studies have addressed specific aspects of ventilation during advanced life support. Some data indicate that ventilation rates during CPR are excessive, although other studies have shown more normal ventilation rates

   An automatic ventilator or resuscitators provide a constant flow of gas to the patient during inspiration; the tidal volume delivered is dependent on the inspiratory time (a longer time provides a greater tidal volume). Because pressure in the airway rises during inspiration, these devices are often pressure limited to protect the lungs against barotraumas.
An automatic ventilator can be used with either a facemask or other airway device (e.g. tracheal tube or supraglottic airway device)

Automatic ventilators should be set initially to deliver a tidal volume of 6–7 ml ‘kg at 10 breaths per minute. Some ventilators have co – ordinated colour markings on the controls to facilitate easy and rapid adjustments for patients of different sizes......and others are capable of sophisticated variations in respiratory parameters

Automatic ventilators provide many advantages over alternative methods of ventilation. These are:

(i) In un – intubated patients the rescuer has both hands free for mask and airway alignment.
(ii) Cricoid pressure can be applied with one hand while the other seals the mask on the face
(iii) In intubated patients they free the rescuer for other tasks
(iv) Once set, automatic ventilators provide constant tidal volume, respiratory rate and minute volume. Thus they may help to avoid excessive ventilation.
(v) Automatic ventilators are associated with lower peak pressure than manual ventilation which reduces intrathoracic pressure, facilitates improved venous return to the heart and subsequent cardiac output.
(vi) Mannikin studies have shown a significant decrease in gastric insufflations when using manually – triggered, flow – limited, oxygen – powered resuscitators compared with a bag – valve mask devices. However human studies have not been done and no data are available

A.1.5 Paediatric Basic and Advanced Life Support

A.1.5.1 AHA Paediatric Guidelines

The asphyxial nature of the majority of pediatric cardiac arrests necessitates ventilation as part of effective CPR, and two large database studies documented worse 30-day outcomes with compression-only CPR compared with conventional CPR. For this reason, conventional CPR (chest compressions and rescue breaths) is a Class I recommendation (LOE B-NR) for children. However, because compression-only CPR is effective in patients with a primary cardiac event, if rescuers are unwilling or unable to deliver breaths, we recommend rescuers perform compression-only CPR for infants and children in cardiac arrest (Class I, LOE B-NR). Conventional CPR (chest compressions and rescue breaths) is a Class I recommendation (LOE B-NR).

A.1.5.2 ERC Paediatric Guidelines

‘Healthcare providers commonly provide excessive ventilation during CPR and this may be harmful. A simple guide to deliver an appropriate tidal volume is to achieve nor-mal chest wall rise. Use a ratio of 15 chest compressions to two ventilations and a compression rate of 100–120 min – 1. Once the airway is protected by tracheal intubation, continue positive pressure ventilation at ten breaths/min without interrupting the chest compressions. Take care to ensure that lung inflation is adequate during chest compressions. Once ROSC has been achieved, provide normal ventilation
(rate/volume) based on the child’s age, and by monitoring end-tidal CO₂ and blood gas values, to achieve a normal arterial carbon dioxide tension (PaCO₂) and arterial oxygen levels. Both hypocarbia and hypercarbia are associated with poor outcomes following cardiac arrest. This means that the child with ROSC should usually be ventilated at 12–24 breaths min⁻¹, according to their age normal values.

‘Bag mask ventilation (BMV) is effective and safe for a child requiring assisted ventilation for a short period. Assess the effectiveness of BMV by observing adequate chest rise, monitoring heart rate and auscultating for breath sounds, and measuring SpO₂. Any healthcare provider with a responsibility for treating children must be able to deliver BMV effectively.

A.1.6 Monitoring of Breathing and Ventilation

‘Monitoring end-tidal CO₂ (EtCO₂) with a colorimetric detector or capnometer confirms tracheal tube placement in the child weighing more than 2 kg, and may be used in pre-and in-hospital settings, as well as during any transportation of a child. A colour change or the presence of a capnographic waveform for more than four ventilated breaths indicates that the tube is in the tracheobronchial tree both in the presence of a perfusing rhythm and during cardiopulmonary arrest. The absence of exhaled CO₂ during cardiopulmonary arrest does not guarantee tube misplacement since a low or absent EtCO₂ may reflect low or absent pulmonary blood flow. Although an EtCO₂ higher than 2 kPa (15 mmHg) may be an indicator of adequate resuscitation, current evidence does not support the use of a threshold EtCO₂ value as an indicator for the quality of CPR or for the discontinuation of resuscitation.

Peripheral pulse oximetry.

Clinical evaluation to determine the degree of oxygenation in a child is unreliable; therefore, monitor the child’s peripheral oxygen saturation continuously by pulse oximetry. Pulse oximetry can be unreliable under certain conditions, e.g. if the child is in circulatory failure.

A.1.7 Conclusions

1. This appendix has presented an analysis of the key points of the 2015 ILCOR guidelines concerning artificial ventilation. There have been no substantial changes from the 2010 guidelines (which are still valid) with the exception of the emphasis on waveform capnography. The interested reader is referred to the original publications of the guidelines listed in the suggestions for further reading listed below.
2. Artificial ventilation remains a neglected area of study in cardiopulmonary resuscitation and this is reflected by the relatively small number of papers that appear each year on the subject. ILCOR notes that the database remains limited and has not conducted a review of artificial ventilation since 2010.

The AHA table of master recommendations is a valuable quick reference for new and existing guidelines.

**Suggestions for Further Reading**


The full ERC and AHA 2015 guidelines are available for free downloading on the following internet websites:


**Appendix 2: Comparing and Selecting Portable Emergency and Transport Ventilators**

**A.2.1 Introduction**

There has been a rapid advance in the design, production and use of portable automatic ventilators over the past 30 years. The result is that there is now a bewildering array of devices on the market covering a wide range of complexity and price. Faced with this situation selecting a suitable portable ventilator from the range available for a specific medical or paramedical service is not easy and there are many factors that should go into making a choice, either for an individual or for a large scale procurement. Examples of various resuscitation and emergency/transport ventilators were presented in Chap. 7. The published technical specifications of these will be consider in appendices 3 and 4. This appendix covers the essential points that should be considered before selecting and using a portable ventilator.
A.2.2 Classes of Available Portable Mechanical Ventilators and Examples

Chapters 7, 8, 9, 10 and 11 have discussed a number of portable ventilators that may be used in emergency and transport ventilation as well as in the management of mass ventilation. In terms of classification these may be conveniently be divided into resuscitation, emergency and transport ventilators. These classes are to some extent arbitrary and the use of ventilator will depend upon many factors such as availability, setting and the training and experience of the operators. Also, as has been seen in earlier chapters of this book ventilators may have uses outside of the intended use, again depending on the setting and availability. Thus ventilators classed as ‘resuscitation ventilators’ may be used effectively in short-term transport and in mass emergency ventilation when no other devices may be available.

A.2.2.1 Resuscitation Ventilators (Single Tidal Volume/Frequency Control, Pneumatically Powered, May be Either Volume or Pressure Generators)

This type of basic ventilator was discussed in Sect. 7.2.1. Essentially these devices are hand-held and are designed to provide immediate life-saving ventilation using only a minimum of controls by responders with basic training in life support. They provide a more reliable ventilation than is possible with the bag–valve–mask.

A.2.2.2 Emergency/Immediate Transport Ventilators (Separate Tidal Volume and Frequency Controls, Time Cycled, Volume Preset, Pneumatically Powered)

This type of ventilator was discussed in Sect. 7.2.2 and is suitable for use by non-specialists in both emergency and immediate transport situations (for example, at the scene of an emergency and during primary transport to hospital. They are also used inside the hospital in the ER and for transport between the ICU and other facilities such as imaging. (Note that MRI compatibility should be checked against the manufacturers’ specifications).

A.2.3 Choosing a Portable Ventilator

Faced with the wide range of ventilators currently available on the market choosing which device will be the most suitable for any one emergency or hospital service may be daunting. This section considers some of the factors which go into choosing a ventilator and how best to approach the task.
A.2.3.1 Factors Determining the Choice of Ventilator

Setting and tasking – where and how the ventilator will be used
Planned requirements – how many units are required?
Who will use the ventilator?
Training and familiarity with the device in non – emergency situations
Supply – availability of suitable agents for the manufacturers
Servicing – can the supplier provide regular servicing for the ventilator. This may be difficult in remote locations.
Costs – these include both the initial outlay and the servicing charges. Apart from cost of the ventilator there may be added continuing costs such as covering the supply of disposable equipment such as filters and patient circuits.

A.2.3.2 Who Should Select the Ventilator?

The selection of the most suitable ventilator should ideally rest with the persons who will be using it. For those unfamiliar with portable ventilators specialist help may be available within the hospital from anaesthetists and intensivists who use ventilators on a regular basis. Such expertise will be helpful in assessing the published technical data.

Allowing the purchase of ventilators to be only in the hands of accounting personnel is not an ideal situation. Purchase of equipment, particularly for stockpiling ventilators for mass ventilation is usually done by tender. There is always the temptation by those in charge of funding to go for the cheapest tender without considering the quality of ventilation that will be provided. Be aware that not all portable ventilators are the same and there is considerable variation in function, particularly in pressure generators (see Chap. 7). These ventilators should not be used in emergency – in certain conditions of increased airway resistance and decreased lung compliance they may deliver inadequate tidal volumes or even may not work at all, jamming during the cycling.

If it is not possible for the potential user to have the final voice in deciding which ventilation should be bought they should at least be part of committee or other body who makes the purchasing decision.

A.2.3.3 Gathering Information Before Buying

Manufacturers will published a certain amount of information about a product in their promotional literature. This may not always cover the function and limitations of the device and it is important to gather as much additional information as possible. The operator’s handbook will usually contain much more information about the design and function of the device and its technical specification and also provide
careful instructions about how the device should be used. Try to see a handbook for the device being considered before buying.

Other useful information can be obtained from manufacture’s sales teams. These will visit potential customers in emergency and hospital services on a regular basis and can also be helpful during trade exhibitions which usually accompany medical congresses. It is always worth visiting such exhibitions to be able to compare the ventilators on display. The following points are important when dealing with sales teams:

- Beware of inflated claims about the ventilator
- Do not be sold something you do not require!
- Always try to see a ventilator working (for example with a test lung) and try the controls before considering purchase further
- Check that the device fully conforms with the regulations of the country where it is to be used. Medical devices must be tested and approached by regulatory bodies such as the Federal Drug Administration in the US. Usually manufacturers will not try to sell a device in a certain country unless full approval has been obtained. This can often be a lengthy and costly business.

There are a number of papers which compare various portable ventilators currently available on the market and these are listed in the suggestions for further reading at the end of this appendix.

A.2.3.4 Testing and Commissioning a Ventilator

If purchasing multiple ventilators (for example in re - equipping an ambulance service or for mass ventilation) always try to buy a single ventilator first and submit it to internal testing by your own service. This is usually done against a calibrated test lung to compare parameters such as delivered tidal volume and oxygen concentration during air mix with the manufacturer’s published data.

Testing a ventilator in the controlled setting of the anaesthetic room is very valuable. Patients who have been anaesthetized and are stabilized on operating theatre ventilators and monitoring equipment can be safely switched to the ventilator being trialed knowing that full back up ventilation and monitoring is available should any problems be encountered. The operator should be fully familiar with the controls and function of the ventilator to be tested by using it on a manikin or test lung before working in a clinical environment.

One problem that may arise in certain countries however is that portable ventilation equipment designed for use in emergency may not be approved for use in hospital settings. This has been a problem in the past with training on field anaesthetic systems. Always check the local protocols before using a new piece of equipment therefore.
A.2.3.5 Training and Use

Once a ventilator has been purchased a complete training programme for those who are to use it should be started. Manufacturers will usually have their own training staff who can train those who are to be involved in the normal medical training on a ‘train the trainers’ basis. Potential ventilator users who have only used bag – valve devices in the past will possibly require extra reassurance about the function of the mechanical ventilator with which they may not be at all familiar. This underlies the importance of being a ventilator that is suitable for the purpose in hand without having too many unnecessary controls.

It is important that portable ventilators should be used as regularly as possible. Their advantages over bag valve ventilation, both in ease of use and the quality of ventilation provided have been discussed earlier in this book but it is important that these advantages should be recognized.

If ventilators are to be stockpiled for use in mass ventilation they should be individually checked and commissioned before stockpiling and, importantly checked on a regular basis in accordance with the manufacturer’s servicing recommendations. This is important whether or not the ventilators have been used.

Suggestions for Further Reading


### Appendix 3: Technical Specifications of Selected Resuscitation Ventilators

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Pneupac VR1</th>
<th>MicroVenT A/C</th>
<th>Carevent BLS/ALS resuscitator</th>
<th>Oxylator EMX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturers’ intended use statements</td>
<td>The Pneupac VR1 is a hand-held portable ventilator intended for use in emergency or transport situations only where the patient is constantly monitored by the user. It offers both automatic and manual release ventilation. The VR1 is intended for emergency resuscitation by medical personnel, paramedics and ambulance technicians inside and outside hospital.</td>
<td>The MicroVenT is a pneumatically powered, time/volume cycled resuscitator with manual triggering for use in conjunction with external cardiac massage, automatic cycling being provided for longer term ventilatory support or patient transport.</td>
<td>The Carevent BLS/ALS resuscitators are hand held devices designed for emergency resuscitation and inter-departmental transport in the hospital environment where the potential patient use is with children and adults.</td>
<td>The Oxylator EMX is pressure limited, flow triggered ventilation device designed to replace the BVM during cardiopulmonary resuscitation and transport. (The manufacturers state that the device is not a demand valve or ventilator but is a patient responsive positive pressure device)</td>
</tr>
<tr>
<td>Target population</td>
<td>Above 10 kg (22 lb)</td>
<td>Above 20 kg (44 lb)</td>
<td>Above 20 kg (44 lb)</td>
<td>Above 10 kg (22 lb)</td>
</tr>
<tr>
<td>Pneumatic power source</td>
<td>Dry, oil free, filtered oxygen</td>
<td>Oxygen or air</td>
<td>Dry, oil free, filtered gas: Oxygen or air</td>
<td>Oxygen</td>
</tr>
<tr>
<td>Input gas pressure</td>
<td>276–1034 kPa (40–150 psi)</td>
<td>45–70 psi (3–5 bar)</td>
<td>345–1034 kPa</td>
<td>3.5 bar (50 psi)</td>
</tr>
<tr>
<td>Patient interface</td>
<td>360° swivelling, reusable, removable patient valve with a flutter valve at the expiratory port. A secondary circuit can be attached to allow ventilation via an ETT</td>
<td>360° swivelling, reusable, removable patient valve with a flutter valve at the expiratory port</td>
<td>360° swivelling, removable patient valve</td>
<td>Mask/ETT connection</td>
</tr>
<tr>
<td>-----------------</td>
<td>---------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>Display and user controls</td>
<td>Tidal volume/frequency control Mode selector dial Manual push button and omni-directional lever</td>
<td>Tidal volume/frequency control Mode selector switch Manual trigger</td>
<td>Tidal volume/frequency control and mode setting selector switch as above with viewing window Manual button</td>
<td>Rotary minute volume control</td>
</tr>
<tr>
<td>Method of operation</td>
<td>Time-cycled, volume-preset flow generator, pressure limited</td>
<td>Time/volume cycled Resuscitator with manual triggering, pressure limited</td>
<td>Pneumatically powered, pressure limited time/volume cycled ventilatory resuscitators</td>
<td>Pressure cycled between 25 and 50 cm H₂O with a constant flow of 40 l/min</td>
</tr>
<tr>
<td>Relationship between tidal volume and frequency control</td>
<td>Interdependent</td>
<td>Independent</td>
<td>Interdependent</td>
<td>n/a</td>
</tr>
<tr>
<td>Tidal/minute volume</td>
<td>A continuous range of tidal volume/frequency with calibration points marked at; 150 ml 300 ml 450 ml 600 ml (detent) 750 ml 900 ml 1050 ml</td>
<td>Continuous tidal volume range from 300 to 1200 ml</td>
<td>Tidal volume range 150–600 ml (GOS) 200–1100 (Standard)</td>
<td>Minute volume range 10–12 l/min in automatic mode</td>
</tr>
</tbody>
</table>

(continued)
<table>
<thead>
<tr>
<th></th>
<th>Pneupac VR1</th>
<th>MicroVenT A/C</th>
<th>Carevent BLS/ALS resuscitator</th>
<th>Oxylator EMX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency</strong></td>
<td>A continuous range of tidal volume/frequency with calibration points marked at:</td>
<td>Continuous range from 12 to 24 BPM (detent 12)</td>
<td>12–20 bpm (detent @ 12 bpm)</td>
<td>Ventilation frequency auto adjusting to lung capacity</td>
</tr>
<tr>
<td></td>
<td>25 bpm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20 bpm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>15 bpm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12 bpm (detent)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11 bpm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 bpm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 bpm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>I:E ratio</strong></td>
<td>1:2</td>
<td>1:2</td>
<td>1:2</td>
<td>1:1 to 1:2</td>
</tr>
<tr>
<td><strong>Flow rate</strong></td>
<td>Output flow rate is determined by the position of the tidal volume/frequency slider and varies between approximately 11–32 l/min.</td>
<td>21.6–43.2 L/min. in automatic mode (32 L/min. at detent)</td>
<td>12–40 l/min. in automatic mode and fixed in manual mode (Standard)</td>
<td>Constant flow at 40 l/min</td>
</tr>
<tr>
<td><strong>Oxygen concentration</strong></td>
<td>100 % oxygen</td>
<td>100 % oxygen</td>
<td>100 % oxygen</td>
<td>100 % oxygen</td>
</tr>
<tr>
<td><strong>Air mix</strong></td>
<td>50 % oxygen</td>
<td></td>
<td>Adjustable 0–50 % oxygen via built – inhalator</td>
<td></td>
</tr>
<tr>
<td><strong>Demand function</strong></td>
<td>Demand flow initiated by breathing effort $\leq 2$ cm H$_2$O in compliance with ASTM F920–93 Demand function also includes ventilator inhibit feature</td>
<td>Respiratory assist whereby patient inhalation triggers restart of inspiratory cycle with approx. $\approx 5$ cm H$_2$O</td>
<td>Demand flow initiated by breathing effort $\leq 2$ cm H$_2$O Demand function also includes ventilator inhibit feature</td>
<td>n/a</td>
</tr>
<tr>
<td>Method of operation in manual mode</td>
<td>In manual (MAN) mode, the user may initiate single breaths up to the selected tidal volume by pressing down the VENT push button or moving the omni-directional lever in any direction. If the user delivers the whole set tidal volume, the ventilator will ‘lock out’ until the appropriate E time has elapsed, whereas if a breath is delivered that does not exceed the set tidal volume, further breaths may be given until the whole set tidal volume has been used.</td>
<td>Operation of manual control provides a continuous flow of gas at 40 l/min. with patient pressure limited by relief pressure valve</td>
<td>Operation of manual control provides a constant flow of gas at 40 l/min.</td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Relationship to tidal volume and frequency control setting when in manual mode</td>
<td>Maximum tidal volume delivered is limited by position of rotary control thus protecting the patient from stacked breaths and over-inflation</td>
<td>None</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Flow rate in manual mode</td>
<td>Output flow rate is determined by the position of the tidal volume/frequency slider and varies between approximately 11–32 l/min.</td>
<td>40 l/min.</td>
<td>40 l/min.</td>
<td></td>
</tr>
<tr>
<td>Spontaneous breathing under power failure</td>
<td>Full spontaneous breathing under power failure with flutter valve permanently fitted</td>
<td>On advanced models, the anti-inhalation valve is fitted so spontaneous breathing under power failure is not possible</td>
<td>Spontaneous breathing under power failure available by omission of anti-air inhalation valve (but entrains surrounding atmosphere)</td>
<td></td>
</tr>
<tr>
<td>Airway pressure limiting system</td>
<td>Pressure relief valve with audible pneumatic alarm set to 40cmH₂O (60cmH₂O optional)</td>
<td>Pressure relief valve with audible pneumatic alarm set to 45cmH₂O (60cmH₂O optional)</td>
<td>60cmH₂O</td>
<td></td>
</tr>
</tbody>
</table>

(continued)
<table>
<thead>
<tr>
<th></th>
<th>Pneupac VR1</th>
<th>MicroVenT A/C</th>
<th>Carevent BLS/ALS resuscitator</th>
<th>Oxylator EMX</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI compatibility</td>
<td>MR Compatible to 3 T and field gradient of 430G/cm.</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PEEP capability</td>
<td>PEEP available with external PEEP adapter when using a patient circuit (secondary configuration)</td>
<td>PEEP available with external PEEP adapter</td>
<td>2–4 cm H₂O</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>95 mm (including patient valve)</td>
<td>90 mm</td>
<td>106 mm</td>
<td>108 mm</td>
</tr>
<tr>
<td>Width</td>
<td>100 mm</td>
<td>55 mm</td>
<td>64 mm</td>
<td>57 mm</td>
</tr>
<tr>
<td>Depth</td>
<td>170 mm</td>
<td>120 mm</td>
<td>150 mm</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>400 g</td>
<td>272 g</td>
<td>400 g</td>
<td>250 g</td>
</tr>
<tr>
<td>Gas consumption</td>
<td>Delivered tidal volume plus approx. 40 ml per breath</td>
<td>Quoted as insignificant</td>
<td>Not specified</td>
<td>Quoted as zero</td>
</tr>
<tr>
<td>Duration of gas supply</td>
<td>At 12BPM and 0.6 l VT approx. 40 min with ‘D’ size cylinder containing 415 l of oxygen at ISO STP (15 °C and sea level)</td>
<td>At mid-setting 34 min with ‘D’ size cylinder containing 370 l</td>
<td>At 20BPM and 0.21 (V_T) approx. 100 min with ‘D’ size cylinder containing 415 l of oxygen</td>
<td>Min time of oxygen supply = cylinder volume divided by 12 l/min</td>
</tr>
</tbody>
</table>

Source: manufacturers’ published literature January 2016
## Appendix 4: Technical Specifications for Selected Emergency/Transport Ventilators

<table>
<thead>
<tr>
<th>Ventilator name</th>
<th>Manufacturer</th>
<th>Country</th>
<th>Ventilator type</th>
<th>Ventilation modes</th>
<th>Ventilation modes</th>
<th>Ventilation modes</th>
<th>Ventilation modes</th>
<th>Ventilation modes</th>
<th>Ventilation modes</th>
<th>Ventilation modes</th>
<th>Ventilation modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilator name</td>
<td>Allied MCV 200</td>
<td>Carevent MRI</td>
<td>GCE Sabre</td>
<td>Medumat transport</td>
<td>Osiris 3</td>
<td>Oxylog 2000</td>
<td>pNeuton</td>
<td>Pneupac parapac plus 310</td>
<td></td>
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<td>-------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEEP</td>
<td>n/a</td>
<td>PEEP – 0-20cmH₂O</td>
<td>Internal adjustable PEEP 0-20cmH₂O</td>
<td>Yes</td>
<td>O – 15 cm H₂O</td>
<td>0–15 cm H₂O</td>
<td>0–20 cm H₂O</td>
<td>Internal adjustable 0–20 cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas supply sources</td>
<td>Central gas supply system Medical gas cylinder</td>
<td>Central gas supply system Medical gas cylinder</td>
<td>Central gas supply system Medical gas cylinder</td>
<td>Central gas supply system Medical gas cylinder</td>
<td>Central gas supply system Medical gas cylinder</td>
<td>Central gas supply system Medical gas cylinder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply gases</td>
<td>Medical oxygen Medical air</td>
<td>Medical oxygen Medical air</td>
<td>Medical oxygen Medical air</td>
<td>Medical oxygen Medical air</td>
<td>Medical oxygen Medical air</td>
<td>Medical oxygen Medical air</td>
<td>Medical oxygen Medical air</td>
<td></td>
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</tr>
<tr>
<td>Supply pressure</td>
<td>280Kpa–600Kpa (2.8–6.0 bar)</td>
<td>45–70 psi</td>
<td>280–600 KPa (40.6–87 psi)</td>
<td>2.7–6 Bar</td>
<td>2.8–6 bar</td>
<td>2.7–6.0 bar/40 to 88 psi</td>
<td>55 +/-15 psi (3.8 bar)</td>
<td>280–600 KPa at 65 l/min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumption of oxygen</td>
<td>7.1 l/min</td>
<td>10.0 l/min (oxygen) 5.2 l/min (air mix)</td>
<td>Check web site</td>
<td>Not specified</td>
<td>11.4 l/min (oxygen) 5.3 l/min (air mix)</td>
<td>9.4 l/min (oxygen) 4.7 l/min (air mix)</td>
<td>Table of consumption in user’s manual 45 min on CPAP from a D – sized cylinder</td>
<td>With a MV of 10 l/min 60 min duration from a 680 l ‘E’ sized cylinder delivering 100% oxygen 160–180 min on air mix</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>115 V/240 V 50/60 Hz 2 AMPS AC</td>
<td>3.6 V Lithium Battery Button cell CR2430 for auxiliary power</td>
<td>100–230 V50–60Hz 8–30 V DC</td>
<td>11–30 V from vehicle with AC/DC converter 230VAC/120VAC</td>
<td>n/a</td>
<td>3.6v Lithium battery for monitoring system (special low magnetic AA battery for MRI and general use)</td>
<td></td>
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</tr>
<tr>
<td><strong>Battery life (hours)</strong></td>
<td>30 h on Oxygen 7 h on Air</td>
<td>n/a</td>
<td>2 years under normal operating conditions</td>
<td>6–14 h</td>
<td>Max 6 h NiCd</td>
<td>n/a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Battery charge time</strong></td>
<td>5 h if off -10 h if in use</td>
<td>n/a</td>
<td>3 h</td>
<td>8 h</td>
<td>n/a</td>
<td>3000 h under normal operating conditions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dimensions</strong></td>
<td>368.3 mm × 261.1 mm × 88.9 mm</td>
<td>100 mm × 240 mm × 194 mm</td>
<td>110 mm × 190 mm × 90 mm</td>
<td>210 mm × 250 mm × 270 mm</td>
<td>123 mm × 215 mm × 208 mm</td>
<td>100 mm × 200 mm × 150 mm 93 mm × 240 mm × 165 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>7.7 kg</td>
<td>check</td>
<td>1.1 kg (ventilator only –check)</td>
<td>5 kg</td>
<td>4.3Kg</td>
<td>2.7 kg 2.4 kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Air mix range</strong></td>
<td>65–100%</td>
<td>60–100%</td>
<td>55–85% at 10mBar</td>
<td>50–100%</td>
<td>60–100%</td>
<td>65–100% 50–100%</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

(continued)
<table>
<thead>
<tr>
<th>Ventilator name</th>
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<th>Pneupac parapac plus 310</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vt range</td>
<td>200–1200 ml</td>
<td>Minute volume 2–14 l</td>
<td>Minute volume 2–14 L/min through 12 settings</td>
<td>50–2000 ml</td>
<td>100–2000 ml</td>
<td>100–1500 ml</td>
<td>360–1500 ml</td>
<td>150–1500 ml (colour–coded controls to match frequency and tidal volume settings for maximum accuracy 8–40 bpm (détente at 12 bpm)</td>
</tr>
<tr>
<td>Frequency range</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I:E ratio</td>
<td>Possible to set 1 s or 2 s Inspiration Time</td>
<td>I:2</td>
<td>59:1 to 1:59</td>
<td>1:3 to 1:1</td>
<td>1:3 to 2:1</td>
<td>Inspiration time 0.6–2.5 s Expiration time 0.6–30 s</td>
<td>1:1.4 to 1:2.5</td>
<td></td>
</tr>
<tr>
<td>Display</td>
<td>LCD</td>
<td>n/a</td>
<td>n/a</td>
<td>LCD colour display</td>
<td>LCD screen</td>
<td>Monochrome LCD</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>User adjustable alarms</td>
<td>High and low pressure alarms Airway Pressure Relief</td>
<td>Airway over pressure alarm</td>
<td>Adjustable pressure relief 20–100 cmH₂O</td>
<td>3–60 mbar</td>
<td>Upper and lower airway pressure limits Fmax Min expired Vt</td>
<td>Paw high-set via Pmax knob Paw low-warning when pressure difference 10mBar is not built up over less than 20 s</td>
<td>High pressure alarm</td>
<td>High and low pressure alarms (visual and audible)</td>
</tr>
<tr>
<td>Additional alarms</td>
<td>Low source gas alarm</td>
<td>Circuit disconnect alarm</td>
<td>Audible disconnect alarm</td>
<td>Audible low pressure alarm</td>
<td>Airway peak pressure alarm</td>
<td>In assist controlled ventilation returns if patient fails to trigger over two cycles</td>
<td>5 audible alarms</td>
<td>5 LED</td>
</tr>
<tr>
<td>-------------------</td>
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<td>------</td>
</tr>
<tr>
<td>Alarm indicators</td>
<td>1-RED LED Audible alarms for high/low pressure Low battery LED indicator</td>
<td>Visual coloured light Audible sound</td>
<td>Not specified</td>
<td>Coloured display</td>
<td>4 LEDS</td>
<td>Audible low a/w pressure alarm</td>
<td>Not specified</td>
<td>LED indicators for high and low pressure, cycling and audible alarms silenced</td>
</tr>
<tr>
<td>MRI compatibility</td>
<td>No</td>
<td>MRI 3 T</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>MRI 1.5 T</td>
<td>Yes – to 3 T</td>
<td></td>
</tr>
</tbody>
</table>

Source: manufacturers’ published literature, January 2016
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