Ventilatory support in the intensive care unit

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Abstract

This article focuses on a classification of modes of mechanical ventilation, the indications for and complications of invasive and non-invasive mechanical ventilation and the recent evidence on adjuncts to mechanical ventilation.

Keywords adjuncts to mechanical ventilation; non-invasive ventilation; positive pressure respiration; ventilators mechanical (classification)

Royal College of Anaesthetists CPD Matrix: 2C02

Learning objectives

After reading this article, you should be able to:

- describe the features of a ventilatory mode which distinguish it from other modes
- list the indications and complications of invasive and non-invasive ventilation
- describe the most commonly used adjuncts to mechanical ventilation

Classification of ventilators

Positive pressure ventilators

Ventilator modes may be classified according to mode of triggering, inspiratory characteristics, mode of cycling, the pattern of mandatory and spontaneous breaths and method of synchronization.

Expiration is passive in all modes except high-frequency oscillation. Positive end-expiratory pressure (PEEP) is almost always applied in critically unwell patients. It increases functional residual capacity (FRC), recruits alveoli, reduces shunt, helps prevent atelectrauma and reduces preload and afterload. A full discussion of the best way to set the level of PEEP is outwith the scope of this article.

Mode of triggering: triggering is the start of inspiration. Ventilators measure pressure, volume, flow and time, and inspiration are triggered when one of these variables reaches a preset value. Breaths may be triggered by the patient or ventilator. If the respiratory rate is set at 10/minute, a controlled mechanical breath will be commenced every 6 seconds (time triggering). For patient-triggered breaths, it is usually a change in flow or pressure which results in the start of a supported spontaneous breath (e.g. pressure support ventilation (PSV) or a mandatory breath (e.g. synchronized intermittent mandatory ventilation (SIMV) in the synchronization window (see below), or assist control ventilation (ACV)). Alternate triggers are possible (e.g. diaphragmatic contraction or chest wall motion in children).

Inspiratory characteristics:

Control mode – ventilators are either pressure controllers, or flow (or volume) controllers. In practice flow and volume controllers behave almost identically (direct control of flow means indirect control of volume and vice versa) and both are called 'volume-controlled ventilation' (VCV). Most VCV uses flow control.

Pressure-controlled ventilation (PCV) versus VCV (Figure 1)

Figure 1 demonstrates the difference between a pressure-controlled and a volume-controlled breath.

With pressure control, inspiratory pressure is chosen by the clinician (2b). Flow in a passive patient is decelerating (2a). With increasing patient effort sine wave flow becomes more prominent. Airway pressure is controlled, but the volume delivered depends on respiratory system impedance and inspiratory time (2c).

Usually with volume control, tidal volume (TV) and inspiratory flow are chosen by the clinician (1a) (inspiratory flow is often set indirectly by choosing the respiratory rate, inspiratory:expiratory (I:E) ratio and TV, e.g. RR 20, I:E 1:2, TV 600 ml = 3 seconds per breath, 1 second for inspiration, therefore inspiratory flow of 36 litres/minute; 1a). Delivered volume is controlled, but airway pressure is dependent on compliance and resistance (for peak pressure, A) and compliance (for plateau pressure, B) (1b).

No benefit in significant outcomes has ever been demonstrated for either mode over the other, and many of the trials of mechanical ventilation use volume-controlled modes. Compared with VCV, PCV has the following theoretical advantages.

- Alveolar pressure is limited and cannot be higher than the set inspiratory pressure.
- Peak airway pressures will be lower for an equivalent TV.
- For a given peak airway pressure, mean airway pressure is higher. Oxygenation may therefore be improved (but will also depend on the plateau pressure and PEEP).
- There may be improved distribution of ventilation. There is less end-inspiratory gradient of pressure among regional units with heterogeneous time constants. CO_2 elimination is improved.

The main disadvantage of PCV is the variation in TV. In addition, when there is vigorous patient inspiratory effort, pleural pressure drops significantly and the transpulmonary pressure (the pressure responsible for alveolar strain-induced ventilator-induced lung injury (VILI)) may be high.

Studies demonstrate that the incidence of VILI is unchanged and there are similar haemodynamic consequences.

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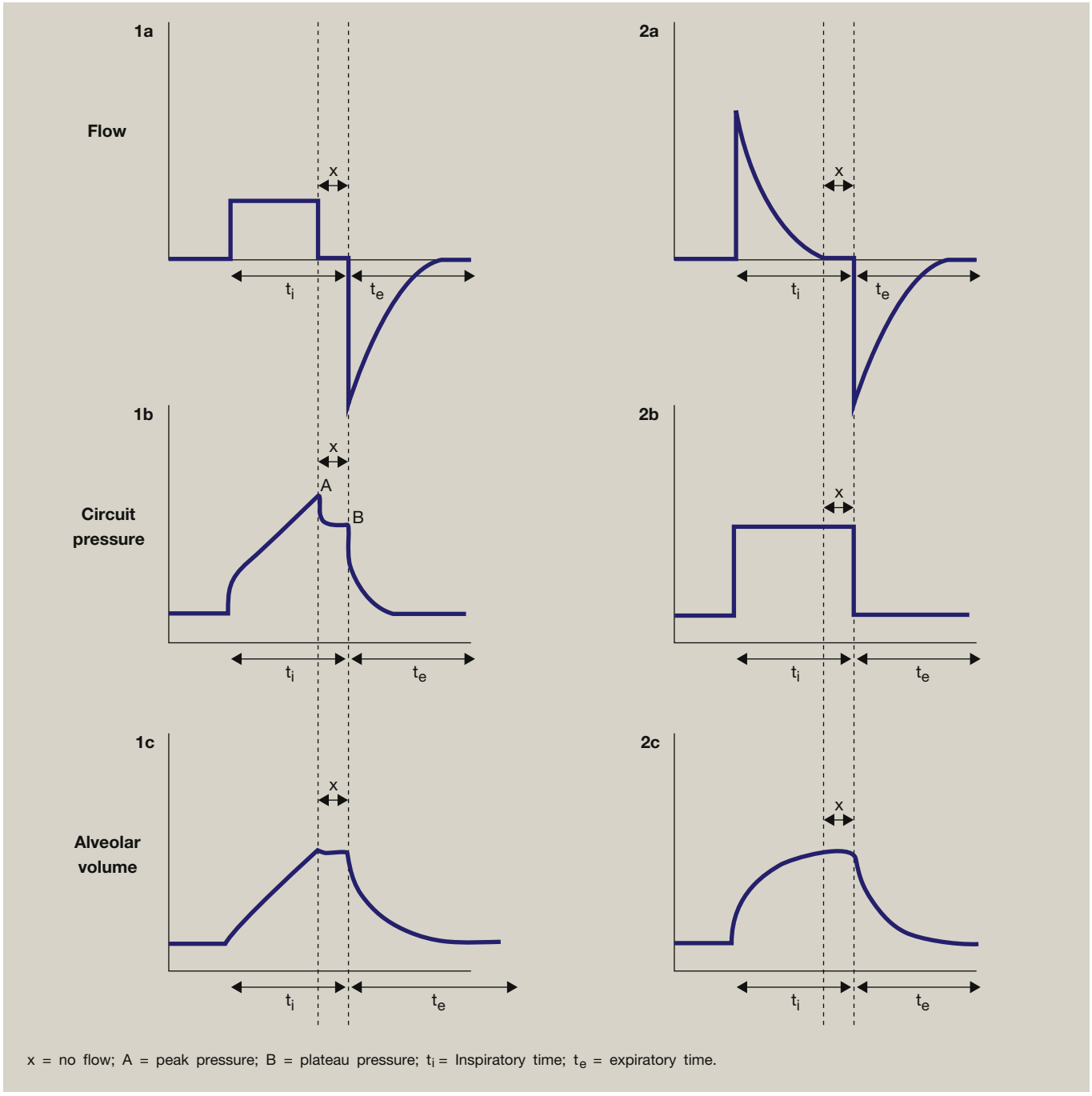

Figure 1 Pressure-controlled ventilation (**2a**–**c**) versus volume-controlled ventilation (**1a**–**c**).

Modern ventilators can deliver breaths with characteristics of both types of breath, called dual control or hybrid breaths (e.g. pressure-regulated volume control, where pressure control and decelerating flow patterns are combined with volume cycling). These modes have the theoretical advantages of pressure controlled breaths, but with more accurate volume control. It is also possible to alter the flow characteristics of volume control breaths on some ventilators – various profiles have been described, for example decelerating or sinusoidal. Definitive advantages of specific flow–time profiles (lower peak pressures or more homogeneous gas distribution) are not clearly established.

Mode of cycling: cycling is method the ventilator uses to end inspiration and allow expiration to start. Expiration is passive. Cycling is also called expiratory triggering and occurs when a preset value of flow, time, volume (or pressure) is reached. Mandatory breaths are generally time cycled (PCV) or volume cycled (VCV). Spontaneous supported breaths (PSV) are usually flow cycled (expiration usually starts at 25–33% of peak inspiratory flow. This is adjustable on many ventilators).

Pressure cycling is now only used as a safety backup for other forms of cycling (i.e. it will terminate the breath if pressure rises to a preset level).

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