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To cite this article use either
DOI: 10.1111/j.2045-0648.2012.00253.x or
Veterinary Nursing Journal Vol 28 pp17-19

Understanding ventilation

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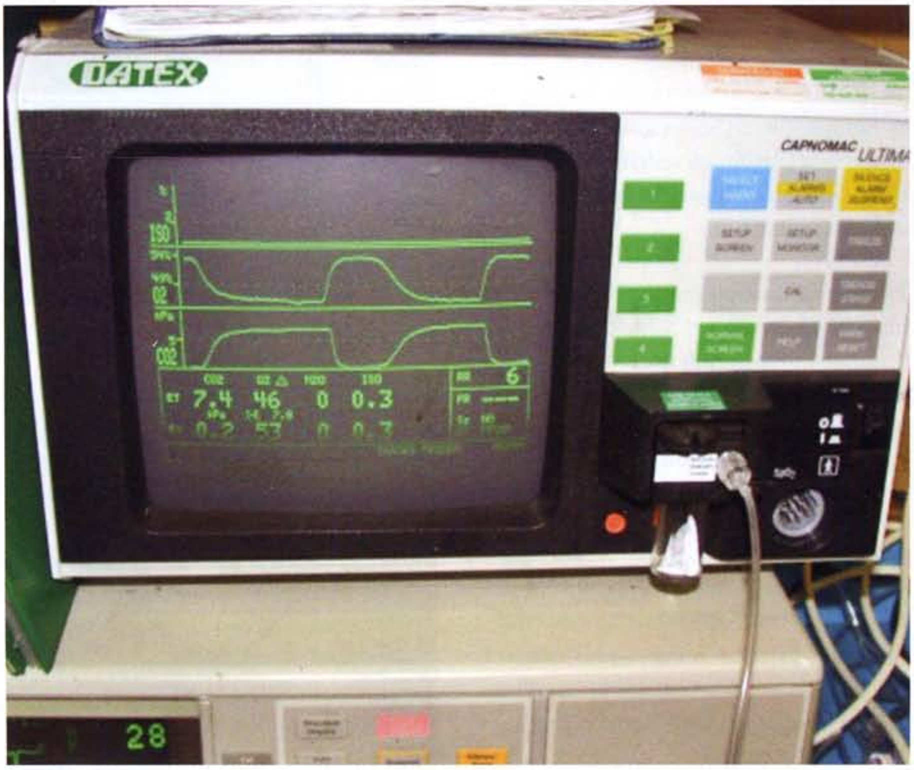
ABSTRACT: To some veterinary nurse anaesthetists, ventilation is misconstrued as just a rhythmic compression of the reservoir bag to provide a breath. While this is a valuable basic method of providing ventilation to a patient, there are many considerations and options available, so it does not need to be reserved for emergency situations. This article will discuss the indications for IPPV, and its physiological and practical considerations.

When a patient is breathing spontaneously, it is an increased level of carbon dioxide (CO_2) which is the primary drive for respiration. Low levels of oxygen (O_2) act as the secondary drive to stimulate the patient to breathe. Carbon dioxide levels change much more readily than O_2 making it a good indicator for ventilation status.

The easiest way to measure CO_2 levels during anaesthesia is with a capnograph (Figure 1). The capnograph measures the amount of carbon dioxide being breathed out during expiration, which is known as end tidal carbon dioxide, ($ETCO_2$). This reflects the alveolar CO_2 and, therefore, systemic arterial CO_2 – providing us with an idea of the efficiency of the patient's ventilation. This makes capnography a quintessential tool for safe and effective ventilation.

Figure 1: A capnograph



Ventilation efficiency can also be monitored through the measurement of arterial blood gases; however, these do not provide us with continuous information.

Pulse oximetry offers information on oxygen saturation of haemoglobin but high concentrations of inspired O_2 can impair the detection of hypoventilation, making it a late – and therefore poor – indicator for the efficiency and requirement for ventilation (Figure 2).

Why ventilate?

It is a common misconception that ventilation should be reserved for apnoeic patients, those receiving thoracic or diaphragmatic surgery or when neuromuscular blockers have been used. However, any patient that is having difficulty ventilating or oxygenating adequately is a candidate for intermittent positive pressure ventilation (IPPV).

Failure to ventilate $PaCO_2$ >60mmHg
Failure to oxygenate PaO_2 <60mmHg or SpO_2 <90 per cent

Assisted or continuous IPPV is indicated in a number of situations. Animals with a low respiratory rate or those unable to reach suitable tidal volumes, such as

Figure 2: Pulse oximetry should be used with caution (image courtesy of Ian Self)

Figure 3a: A 7.56kg patient unable to achieve an adequate tidal volume (23mls) owing to its obesity.

Figure 3b: Capnograph pattern is not normal as breaths are short

obese patients or those with lung disease are good candidates (Figures 3a and 3b).

Anaesthetics and sedatives can induce respiratory depression as they reduce the respiratory response to carbon dioxide levels in the blood ($PaCO_2$). This means that a higher $PaCO_2$ is required to achieve the same ventilation. Because of this this reduced response to stimulation by $PaCO_2$, patients may not be achieving adequate gaseous exchange. This is particularly common when potent opioids are used or when common induction agents are administered too quickly.

Patients who are tachypnoeic may also benefit from IPPV to maintain a stable plane of anaesthesia (Figure 4).

Animals undergoing thoracic or diaphragmatic surgery will be unable to achieve the negative pressure

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Figure 4: A tachypnoeic patient exhibiting low $ETCO_2$ and re-breathing of expired CO_2

Figure 5: Capnograph of patient with poor SpO_2 being mechanically ventilated

necessary to achieve adequate respiration and will, therefore, require ventilating.

Patients who are failing to oxygenate adequately despite oxygen therapy will require ventilatory support. These patients are usually defined as having an SpO_2 <90% on room air or 95 per cent on oxygen ($PaCO_2$ of <60mmHg if measuring blood gases) or being cyanotic (Figure 5).

Patients with suspected increased intracranial pressure (ICP) should be ventilated to maintain normocapnia. Hypercapnia can further increase the ICP by vasodilation, which may contribute to herniation. Moderate hyperventilation – maintaining $ETCO_2$ at 30-5mmHg – will cause vasoconstriction and reduce this risk without comprising perfusion to the brain.

The main aim is to restore oxygenation and ventilation to acceptable levels. This should be attained while minimising harmful effects.

Practical considerations

Mechanical ventilators were designed to provide relief for the anaesthetist, leaving him or her free to monitor the patient. However, there are advantages and disadvantages to both mechanical and manual methods (Table 1).

An appropriate breathing system should be selected. The Magill and Lack circuits are not suitable for prolonged IPPV as they are much less efficient than spontaneous respiration and require the fresh gas flow rate to be doubled in order to prevent the patient from re-breathing exhaled carbon dioxide. Adequate pauses between breaths, resulting in a slow respiratory rate, are also necessary to allow enough time for venous return to the heart and for exhaled gases to be flushed out of scavenging.

Ayres T-piece, Bain and circle systems are all suitable for continuous IPPV. They are more efficient than during spontaneous

Figure 6: IPPV on a Bain system

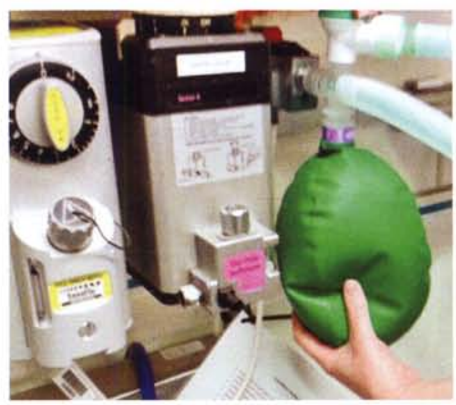

Figure 7: IPPV on a modified Ayres T-piece

TABLE 1 Comparison of mechanical and manual ventilation methods

	Advantages	Disadvantages
Mechanical	• Accurate settings • Leaves anaesthetist available to monitor patient	• Equipment is expensive • Problems may not be noticed as quickly • Requires additional staff training
Manual	• Aware of problems instantly • Quick and easy • Can titrate each breath	• Inaccurate • Likely risk of high pressures and over-inflation • Tedious • Requires another anaesthetist to monitor

respiration. Their fresh gas flow rate may be decreased by up to half without risk to the patient (Figures 6 & 7).

Manual ventilation should be gentle and rhythmic and provide the patient with an appropriate tidal volume. Emptying the reservoir bag with the adjustable pressure limiting (APL) valve closed will over-inflate the lungs, potentially resulting in barotrauma. It is, therefore, important to work out the patient's tidal volume (10-15mls/kg) before initiating IPPV. Squeezing the bag when the animal breathes in will augment the tidal volume. This is assisted ventilation. Controlled respiration is when the anaesthetist manages the rate and volume.

There are number of mechanical ventilators available for use on veterinary patients. It is essential that the anaesthetist understands both the positive features and the limitations of the ventilator available to them.

Mechanical ventilators can be controlled by either volume or pressure. Volume-controlled ventilators ensure a constant tidal volume regardless of compliance or resistance. Pressure-controlled ventilators ensure a constant pressure, which minimises the chance of trauma, but does mean tidal volume will vary as compliance changes.

Not all machines will allow for ventilation of patients of every weight, although some provide an interchangeable valve. This allows the user to ventilate patients under 10kg on a paediatric valve and patients over 10kg on an adult valve. Changing the valve, however, does alter the way in which the ventilator is controlled, making is essential that the user has a complete understanding of the tool they are using.

Potential complications and avoiding them

The respiratory rate, $ETCO_2$, tidal volume and peak inspiratory pressure should ideally be monitored because they all provide key information about efficiency of ventilation (Figure 5).

Table 2 shows values which should be controlled and the potential complications that may arise.

APL valves have a safety release, allowing them to open once pressures of $60cmH_2O$ are reached as the maximum safe pressure of intact lungs in a healthy patient is $70cmH_2O$. Patients who have lung disease – or who have experienced recent trauma – will have a lower threshold to barotrauma (<$40cmH_2O$ and damage can be done to the lungs before the valve is released.

These are the patients who are most routinely ventilated, so this is an important factor to take into consideration.

Returning to normal

Often the requirement for ventilation is no longer present when the procedure is finished as anaesthetic drugs which may have had respiratory depressive effects can also be stopped.

Patients should still be monitored closely as some may require a degree of support until normal spontaneous respiration returns. A few breaths per minute can be given, allowing the carbon dioxide levels to increase and stimulate respiration.

If neuromuscular blockers have been used, extra caution is required to ensure their effects have ceased before stopping ventilation.

TABLE 2 Values to control and potential complications

Value	Potential problem	Action
Peak inspiratory pressure	High pressures can cause lung damage	Maintain at 8-15cmH_2O Do not exceed 20cmH_2O
$ETCO_2$	Levels of 45-60mmHg stimulate respiration which may not be desired whilst ventilating a patient. Levels above 60mmHg cause apnoea. High levels may reduce cerebral perfusion. Acid base disturbances.	Maintain at 35-45mmHg
Tidal volume	High tidal volume may result in over-inflation of lungs, increased pressure and trauma to lung tissue. Low tidal volume may result in inadequate gaseous exchange.	Monitor and adjust tidal volume as necessary.
Respiratory rate – inspiratory:expiratory time	Leaving adequate time between breaths allows for venous return to the heart and helps maintain normocapnia.	Maintain respiratory rate similar to normal and inspiratory:expiratory time of 1:2.