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Artificial ventilation and the small animal operating theatre

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ABSTRACT: Ventilation is the process that allows exchange of gases into and out of the lungs, which occurs through the action of inspiration and expiration. This is vital for oxygen (O_2) delivery to the lungs, for blood transportation to the tissues and excretion of carbon dioxide (CO_2) from the body. Spontaneous ventilation occurs in conscious healthy patients. However, the ability to maintain a controlled airway and normal ventilation is one of the most important aspects of ensuring safe general anaesthesia. This article focuses on artificial ventilation of anaesthetised patients in the small animal operating theatre. The initial section discusses the role of intermittent positive pressure ventilation (IPPV), the primary indications of and when to initiate, important monitoring values and potential complications. The second section illustrates the classification, set up and practical use of the Penlon Nuffield 200 Ventilator.

Intermittent positive pressure ventilation (IPPV) may be accomplished by manual compression of the re-breathing bag against a closed adjustable pressure-limiting (APL) valve, or by using an automatic ventilator. In small animal practice, manual ventilation is the more common method of delivering artificial ventilation. Nevertheless, mechanical ventilation is a more efficient and reliable means of maintaining assisted or controlled respiration.

By allowing the provision of IPPV, automatic ventilators gain control over respiratory variables, such as respiratory rate and tidal volume. By providing continuous and controlled respiration, ventilators are invaluable and allow the veterinary nurse to undertake other aspects of patient monitoring that are not possible to achieve whilst ventilating manually.

Indications for IPPV

IPPV is indicated to support any patient that is unable to ventilate adequately and/or is experiencing difficulty oxygenating (as a consequence of respiratory failure). This may be defined as a condition in which the pulmonary oxygen (O_2) is severely compromised, to the extent that oxygen supply to the tissues and/or the removal of carbon dioxide (CO_2) from them is insufficient.

Anaesthetised patients, particularly the obese and those with pre-existing pulmonary disease that are subject to upper abdominal or thoracic surgery, are predisposed to respiratory failure.

IPPV can cause irregular ventilation affecting pulmonary capacity. However, during surgical procedures involving an open thoracic cavity, patients lose the ability to inflate their lungs and are consequently unable to expand their thorax owing to a loss of negative pressure. In addition, the administration of neuromuscular blockade abolishes a patient's ability to respire spontaneously. Artificial ventilation is, therefore, an absolute indication in such cases.

Potential complications and vital monitoring

When performed correctly, artificial ventilation assists in maintaining continuous general anaesthesia and the likelihood of complication is minimal. If carried out inappropriately, however, for example when high inspiratory pressures are used, IPPV can cause severe detrimental effects on the lungs, including volutrauma (over distension of the alveoli) and barotrauma (rupture of the alveoli).

These are more likely to be complications of manual ventilation because the amount of pressure being exerted on the lungs cannot be assessed or controlled as well as with mechanical ventilation. This is particularly important in patients with suspected or known lung contusions, which can cause lung tissue to become very fragile; thus increasing the risk of pneumothorax.

IPPV should always be performed on intubated patients and never attempted via a face mask, because this is likely to cause inflation of the stomach. Cuffed endotracheal tubes (ETTs) should not be used routinely in cats owing to the risk of damaging and, consequently, narrowing the respiratory tract. However, during ventilation, leaking will occur around the ETT and the set pressure will not be reached. Therefore a cuffed ETT should be used with extreme caution.

The majority of anaesthetic agents cause dose-dependent respiratory depression, thereby affecting a patient's ability to ventilate suitably whilst anaesthetised. Therefore, the administration of volatile anaesthetic agents and injectable drugs – particularly potent opioids, such as fentanyl (Sublimaze, Martindale Pharmaceuticals) – can cause excessive respiratory depression.

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In anaesthetised patients with normal lung physiology and high concentrations of inspired O_2, respiratory failure is most commonly a consequence of mild to moderate hypoventilation (reduced or deficient ventilation). In the majority of cases, end tidal carbon dioxide ($ETCO_2$) levels are correspondingly high (hypercapnia – increased level of CO_2 in the blood) with accompanying hypoxia (a normally low O_2 supply in the blood).

Artificial ventilation is consequently most commonly performed to correct hypoventilation, thus returning $ETCO_2$ to within normal values (normocapnia) (35-45mmHg). A normal capnographic curve indicates that the value shown for $ETCO_2$ is most likely an accurate representation. In addition, it provides an estimation of ventilatory adequacy by detecting apnoea (temporary cessation of respiration) and hypoventilation.

Alveolar CO_2 levels are approximately equal to arterial CO_2 levels. Capnography, therefore, provides a precise, continuous and non-invasive (indirect) monitoring method, thus decreasing the requirement for invasive (direct) arterial blood gas analysis.

Mild hypercapnia (values into the mid-50s) is common during general anaesthesia; it helps support blood pressure and is usually well tolerated. In this situation, IPPV is not normally indicated. However, levels above 60mmHg may introduce disadvantageous effects such as bradycardia (excessive slowing of the heart) and depression of the myocardium. When this is the case,

Figure 1: The Penlon Nuffield 200 ventilator

Figure 2: Standard valve

Figure 3: The Newton valve

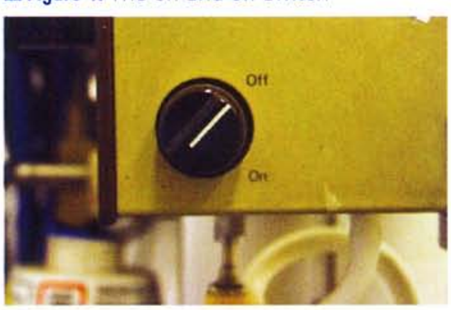


Figure 4: The on and off switch

Figure 5: Inspiratory control

artificial ventilation should be commenced but not prior to excluding complications, such as pneumothorax, ETT obstruction, equipment failure and excessive dead space.

If a mechanical ventilator is being used, the ventilatory settings should consequently be adapted to elevate minute ventilation in order to return and maintain an acceptable $ETCO_2$ reading. This can be achieved by increasing the respiratory rate and/or tidal volume. However, an excessively high respiratory rate must be avoided to prevent intrinsic (incomplete exhalation) positive end expiratory pressure (PEEP) (alveolar pressure). An elevation in intra-thoracic pressure (ITP) during inspiration reduces venous return; thus decreasing cardiac output.

In addition, ITP is likely to increase intra-cranial pressure (ICP). In patients with cardiac disease and known or suspected raised ICP care must be taken to maintain $ETCO_2$ of around 30mmHg.

It's not uncommon to cause hyperventilation (excessively rapid and deep respiration) resulting in hypocapnia (decreased CO_2 levels in the blood) whilst performing IPPV and not monitoring $ETCO_2$. Hypocapnia should be monitored with caution as CO_2 is the main ventilatory drive. If hyperventilation results in severe hypocapnia, the continuation of spontaneous ventilation may become challenging, although this is more commonly a difficulty with patients that have been subject to prolonged ventilation, such as in an intensive care setting. In addition, hypotension (decreased blood pressure) may occur as a result of hypocapnia.

Use of mechanical ventilators

Mechanical ventilators vary considerably in their complexity and it is, therefore, difficult to standardise knowledge and information, or provide an illustration of their use. There is, however, a marked difference between the role of the ventilator in an intensive care setting for a patient with pulmonary pathology, and its role in the anaesthetised surgical patient.

In the small animal operating theatre, ventilation is performed for limited time periods on patients with predominantly normal lung physiology. The majority of theatre ventilators are, therefore, relatively simple in design and function. These ventilators are intended to amalgamate with anaesthetic circuits to deliver the patient varying concentrations of O_2, air, nitrous oxide (N_2O) and volatile agent.

Appropriate breathing systems

Breathing systems that are appropriate for prolonged IPPV are the circle, Ayres T-piece and the Bain. The Lack and Magill are only suitable for short-term artificial ventilation as re-breathing of expired air causing hypercapnia can otherwise occur. These circuits should, therefore, be exchanged for an acceptable system when IPPV is required in the longer term.

Ventilator classification

The majority of ventilators are volume or pressure controlled. Volume-controlled ventilators provide a constant gas flow during inspiration, whereas pressure-controlled ventilators deliver a constant pressure of gas during inspiration.

The Penlon Nuffield 200 Ventilator

Penlon Ventilators are common in small animal practice. The Penlon Nuffield 200 is a pneumatically driven, time-cycled ventilator with preset volume and flow rate (Figure 1). This allows breaths to be delivered at fixed intervals and inspiration is ceased when the fixed inspiratory time has expired. In addition, it allows the operator to vary the inspiratory and expiratory time, plus the pressure in which the gas is delivered to the patient.

This model is used with either a standard valve (Figure 2) or a Newton valve (Figure 3). The standard valve is appropriate for patients weighing more than 10kg. This can, however, be quickly and easily replaced with a Newton valve, converting the ventilator to a pressure generator on an Ayres T-piece or Bain breathing system. This enables low tidal volumes to be delivered, making it suitable for smaller animals, weighing between 100g and 10kg.

Ventilator settings

The ventilator consists of four controls. They provide a range of settings allowing a constant gas flow during inspiration. In addition, variation of I:E (time of inspiration versus expiration) settings are possible.

The on/off switch commences and ceases mechanical ventilation (Figure 4). The inspiratory control (Figure 5) sets the time of inspiration (0.2-2 seconds) and the expiratory control (Figure 6) sets the length of time between respirations (0.5-4 seconds).

A normal I:E ratio is 1:2, therefore expiration is twice the length of inspiratory time. An insufficient ratio does not allow for adequate gas exchange to occur; thus increasing ITP – decreasing venous return and, consequently, cardiac output.

The flow rate (Figure 7) controls the level of pressure delivered on inspiration (0.25-1 litre per second). The pressure gauge illustrates peak patient airway pressure (Figure 8). This should not rise above 8-10cmH_2O in cats and 10-12cmH_2O in dogs, to prevent lung injury. It is, therefore, vital that this is continually monitored during mechanical ventilation.

Figure 6: The expiratory control

Figure 7: The flow rate

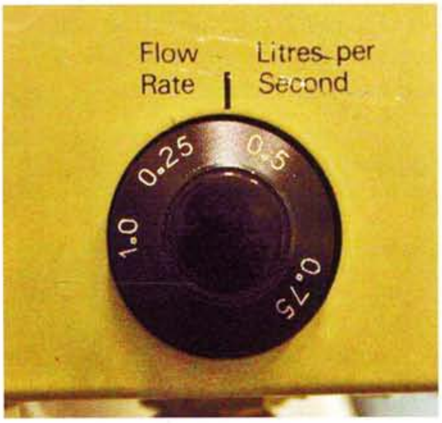
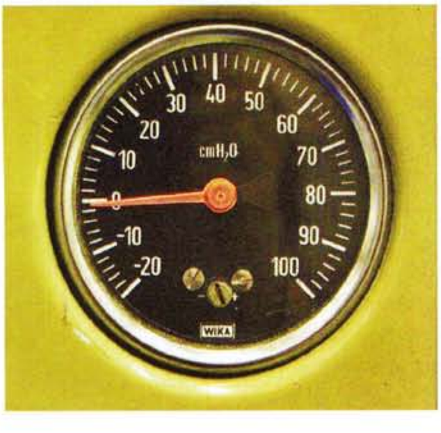


Figure 8: The pressure gauge



Ventilator set-up

First, as with an anaesthetic machine, a ventilator should always be checked for defaults prior to use. The appropriate valve should then be selected (standard or Newton) prior to its being attached to the fitting located underneath the ventilator (Figure 9). The pressure gauge valve, which is also found on the underside of the machine, should then be connected (Figure 9).

Following this, check that the scavenger is fixed to the expiratory port of the ventilator valve (Figure 10).

Last, a length of tubing should be attached from the inspiratory port of the ventilator to the bag port on the breathing system (Figure 11) – the ventilator takes the place of the re-breathing bag in a circuit. The APL valve must be closed.

Ventilating the patient

Before turning on the ventilator, the expiratory time should be set to four seconds and it is important to ensure that the pressure control is on the lowest setting (0.25 litre per second) to prevent over-exertion of the lungs, and once again, potential injury.

Once the ventilator is switched on, the pressure can be increased incrementally until chest-wall movements are appropriate and the required inspiratory pressure is reached. The respiratory rate can then be adjusted by increasing or decreasing the expiratory time in order to maintain $ETCO_2$ within normal values. A normal respiratory rate should be targeted.

When using a circle system, the oxygen flow rate usually required is 500ml-1 litre per minute. However, always ensure that continuous pulse oximetry and capnographic monitoring is in place. Higher rates are required when using an Ayres T-piece.

Occasionally, it may be necessary to hyperventilate initially in order to lower the $ETCO_2$ values to suppress a patient's respiratory drive, although the majority of anaesthetised patients hypoventilate mildly and efforts to spontaneously respire ('bucking' the ventilator) during ventilation are uncommon.

If normocapnia is maintained, however, and spontaneous breaths are attempted,

Figure 9: Valve and pressure gauge attachment

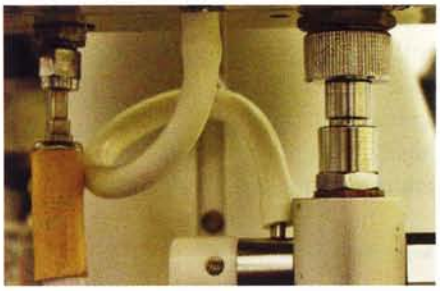
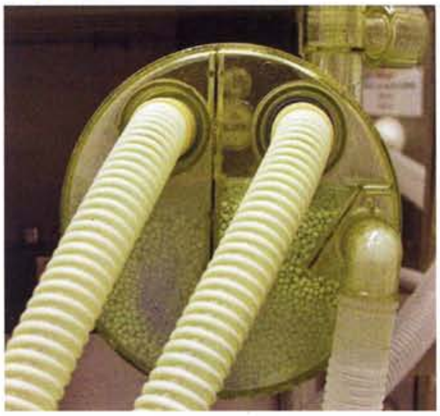


Figure 10: Scavenging attachment to expiratory port

Figure 11: Ventilator tubing



this is usually a result of inadequate anaesthesia or analgesia. These areas should, therefore, be immediately assessed.

How to stop using the ventilator

The volatile agent and ventilator should be switched off before the ventilator tubing is detached, the re-breathing bag is replaced and the APL valve is opened. The scavenger from the ventilator valve must be returned to the circuit before the vaporiser is turned back on. Manual IPPV should then be commenced to reproduced a normal respiratory rate, allowing the return of normocapnia in order for spontaneous ventilation to reinitiate.

Conclusion

This article has provided the reader with a useful overview of the role of mechanical ventilation in the small animal operating theatre, whilst highlighting potential difficulties and important monitoring values.

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NEWS REVIEW
by Jean Turner

Professional indemnity

The Veterinary Defence Society has a policy for RVNs. This will cover members for investigations of professional complaints against them, which will of course be investigated by the Royal College of Veterinary Surgeons.

For details of the policy, contact the veterinary nurse section of the VDS website, www.thevds.co.uk.

RCVS Trust Library

Apart from housing a superb collection of historical books, the RCVS Trust Library is an excellent source of information and is widely used by research students.

Membership of the library is open to RVNs and the current fee is £33 per annum. This will provide information to support your Degree or Diploma studies.

For details visit www.rcvslibrary.org.uk, where you can search the library catalogue, order documents and see the full range of services on offer.

Pets are good for people ... and for Government

The Pet Advisory Committee (PAC), using the Government's own figures, estimates that pet lovers spent almost £6 billion in 2010 and contributed more than £2 billion a year to the nation's coffers in taxes.

Additionally there are other less visible benefits that help balance the Chancellor's books. Independent studies indicate that the health benefits of pet ownership (and around of half of UK households do) effectively save the NHS as much as £1.5 billion a year.

As the Euro crisis deepens, other Finance Ministers in the EU should also take note. Throughout the EU in 2010, owners spent €29 billion on their pets (equating to €12 billion in tax revenues) and social scientists studying the health benefits of pet ownership in Germany estimated savings of €5.5 billion annually.

The Pet Advisory Committee points out that not everything, however, can be reduced to hard cash terms – as chair, Tracey Crouch MP, says: "What this research shows is the positive contribution pets and their owners make to the economy and towards a healthy society.

"While the contribution to the economy is easier to identify, the companionship, interaction and exercise pets can give to their owners – in particular the elderly – and the effect this has on their well-being, is of equal worth to individuals and society as a whole."

For more information, visit www.petadvisory.org.uk

EBVM symposium – a first for UK

The UK has played host to its first-ever symposium on evidence-based veterinary medicine (EBVM). The event, held in London at the end of October, was organised by the Royal College of Veterinary Surgeons (RCVS) Charitable Trust.

Over 160 delegates from veterinary practices, academia, industry, veterinary publishing and veterinary policy organisations attended the event; which aimed to discuss lessons learned from human medicine, and to encourage the development of a forward-looking strategy for implementing EBVM practice.