**Advanced Oxygen Delivery Methods: Thinking Outside the Oxygen Cage**

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Oxygen administration is frequently used in veterinary medicine to treat hypoxia. Noninvasive or conventional oxygen administration methods are readily available in most hospitals or clinics and don't require specialized equipment or skills to administer to the patient. Conventional oxygen therapies include nasal cannula, oxygen cage, hood oxygen and flow by/mask administration. With conventional oxygen therapy (COT), FIO2 is limited to 30–75% and no significant pressure support is provided. In patients with severe hypoxemia (PaO2 < 60 mm Hg) who fail COT, more aggressive treatment is warranted. The purpose of this lecture is to describe advanced oxygen therapy techniques that could be used in small animal patients. Advanced oxygen therapies can be divided into two groups:

* Advanced invasive oxygen therapies requiring intubation.
* Advance noninvasive oxygen therapies: advanced oxygen delivery methods that do not require intubation. In this presentation, only high flow oxygen therapy will be developed.
1. Conventional oxygen therapy

Conventional oxygen therapy can be supplied from various sources (eg, centralized in-house oxygen, portable oxygen tanks, anesthetic machines) and in many different ways, depending on the severity of respiratory distress, the need to handle the patient while providing oxygen, the duration supplementation is needed, the available equipment, and the clinical experience and skills of the clinician. Pro and cons of the different COT are described below.

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| --- | --- | --- | --- |
| **Oxygen administration technique**  | **Oxygen concentration attainable** | **Advantage**  | **Limitations** |
| **Flow-by** | 25-40% | * Easy to implement
* Keep patient accessible for examinations and procedures
 | * Might stress patient
* Limited FiO2
* Requires someone to hold tubing
* Only useful short-term
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| **Face mask** | 50-60% | * Easy to implement
* Higher FiO2
* Keep patient accessible for examinations and procedures
 | * Might stress patient
* Can cause rebreathing of CO2 if mask is too tight
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| **Elizabethan collar** | 30-40% | * Higher FiO2
* Limited equipment
* Keep patient accessible for examinations and procedures
 | * Might stress patient
* Humidity, CO2, and temperature can increase in the hood
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| **Nasal**  | Up to 80% with bilateral catheters | * No operator required
* Allows transport, examinations and care without discontinuing oxygen
 | * Not tolerated in all patient
* Difficult in brachycephalic
* Panting can reduce effectiveness
* Nasal irritation
 |
| **Oxygen cage**  | Up to 100% | * Minimizes patient stress, allowing stabilization
* Higher FiO2
 | * Limited to no patient access
* Expensive to purchase equipment and use
* Oxygen concentration rapidly fall when door is opened
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Fortunately, COT provide adequate oxygen support for the majority of our patients.

When COT fails to improve respiratory distress in dogs and cats, mechanical ventilation is currently the only reliable technique to improve the patient’s oxygenation. However, mechanical ventilation is expensive, requires high level of cares and its invasive character is associated with high complication rate.

1. Mechanical ventilation: indication and cares

Patients are placed on a ventilator for three main reasons:

* Severe hypoxemia despite oxygen supplementation (PaO2 < 60 mmHg with oxygen or SpO2 < 90%)
* Severe hypoventilation despite therapy (PCO2 > 60 mm Hg)
* Excessive respiratory effort with impending respiratory fatigue or failure.

It has been suggested that patients requiring short-term ventilation have better outcomes than patients requiring long-term ventilation1. Multiple complications associated with long-term ventilation have been documented, many of which are related to nursing care issues2. These include oral and corneal ulceration, tracheal tube occlusion or dislodgment, and gastric distension requiring decompression. The importance of nursing care for ventilator patients in human medicine is highlighted by an increased risk of late- (but not early-) onset ventilator-associated pneumonia (VAP) with lower nurse staffing level3. Ideally each patient on the ventilator will have a dedicated veterinary technician at all times.

* 1. Airway management

Airway management and monitoring is of high importance to avoid VAP and VILI (ventilator induced lung injury). Airway management consists of endotracheal tube (ET) care, humidification of the airways and airway suctioning.

1. Care of the endotracheal tube

Patients undergoing mechanical ventilation need intubation with either an ET or a tracheostomy tube. Ideally the ET tube should be sterile and have a low-pressure cuff and the intubation process performed with sterile gloves. Whenever the airway is being handled after intubation, hand hygiene should be performed first, and examination gloves used. To help prevent tracheal necrosis, it has been suggested to deflate the cuff and reposition it every 4 hours in veterinary medicine.

1. Humidification of the airways

Lack of humidification leads to increased mucus viscosity and volume, which can cause ET tube occlusion, tracheal inflammation, and depressed ciliary function. There are two major methods of airways humidification: heat and moisture exchangers (HME) and hot water humidifiers. The choice to use one method instead of the other depends on both technical and economic considerations. HMEs are more often used nowadays because they are simple to use and cost-effective. Their performances are for several models comparable to those of a heated humidifier. They are usually changed after 24 h of use. It has recently been shown that some HMEs can be changed only every 48 h and that at least one HME can be changed only once a week in some patients4. Humidification could also be done with nebulization of saline, synchronized with the inspiration. Other nebulized medications that could be used in ventilated patient are hypertonic sodium chloride (…%) (mucolytic action, increased muco-ciliary function, anti-inflammatory), antibiotic when infectious disease is suspected (e.g.: Gentamicin), and heparin (specially in case of ARDS and ALI induced by smoke inhalation).

1. Airway suctioning

Suctioning of the airway is of key importance to help prevent ET tube occlusion with airway secretions. In the awake patient, coughing helps clear secretions; however, the cough reflex is blunted or absent in the anesthetized patient. Suctioning can be performed by either an open or closed system suction method. It should be performed every 4 hours or more frequently on an as-needed basis; and in a pre-oxygenated pet.

Specific techniques of chest physiotherapy can help expectoration of secretion in ventilated patient and will be developed during the lecture.

* 1. Specific organ cares

Oral, eye, urinary, gastrointestinal and recumbent patient care is mandatory. Patients anesthetized for prolonged periods such as ventilated patients can develop a significant number of complications involving these organs5. The eyes should be kept well lubricated to prevent ulceration. The mouth should be regularly cleaned of secretions and flushed with an oral rinse (e.g., Chlorhexidine) and a glycerin solution should be applied to the tongue to help prevent lingual drying and damage. Ideally, urinary tract care should involve a urinary catheter being placed to keep the patient clean and dry (as well as providing the added benefit of being able to monitor hydration status and kidney function). Just be aware that it carries the risk of development of bacteriuria either from true urinary tract infection or colonization of the catheter. So, urinary catheter care should be performed every 8 hours. Nutritional support of ventilator patients can be quite challenging as they are usually sedated, if not fully anesthetized, and unable to protect their airway making them high risks for regurgitation and aspiration.

Furthermore, anesthetic ileus can be an issue if enteral feedings are to be administered. Gastric distention should be monitored for closely and gastric residual volumes should be assessed if possible prior to feedings. Enteral nutrition in mechanical ventilation carries risks and benefits. Enteral feeding may be delivered via a nasogastric, gastrotomy, or jejunostomy tube6. In light of these previously stated concerns, these patients become good candidates for parenteral nutrition instead.

Body positioning should be changed every 4-6 hours and adequate padding should be provided on ventilator patients because they are at high risk for pressure sores and nerve damage. Passive range of motion exercises should also be part of the patient care as these patients are prone to muscle atrophy especially if they are on the ventilator for longer than 48 hours.

* 1. Monitoring

Other parameters that should be monitored on ventilator cases include electrocardiograph monitoring, pulse oximetry, capnography, arterial blood pressure and continuous temperature. The different probes should be replaced every 4 hours to avoid tissue damage. When possible, these patients should have an arterial catheter for routine arterial blood gas sampling and invasive pressure monitoring. Blood pH, glucose, lactate and electrolytes should be serially monitored as well, especially if parenteral nutrition is being administered.

1. Noninvasive advanced oxygen therapy: focus on high flow oxygen therapy

High flow oxygen therapy (HOT) is a nasal oxygen delivery system that has been used in people for over 10 years but is relatively new to veterinary medicine. High flow nasal cannula accurately delivers humidified and heated oxygen to the patient.

HOT is carried out using an air/oxygen blender, active humidifier, single heated tube, and specific nasal cannula (Picture 1). Those specific nasal cannulas should ideally be 50% or less the diameter of the nares.



*Picture 1: High flow nasal cannula in place in a 2-month-old dyspneic English Bulldog*

Able to deliver adequately heated and humidified medical gas at higher flows than COT, HOT is considered to have a number of physiological advantages, including reduced anatomical dead space, PEEP, constant FIO2, and good humidification. Initial studies looking at the use of HFNC in veterinary patients have been encouraging.

A pilot study looking at healthy dogs showed a significant increase in PaO2 in dogs receiving HOT at 20 and 30 L/min compared to dogs receiving conventional nasal oxygen at 100 ml/kg/min7. A retrospective study looking at 6 dogs undergoing HOT for hypoxemia not responsive to conventional oxygen therapies showed that hypoxemia resolved in 4/6 dogs with HOT8. Moreover, this study showed that HOT was well tolerated and with few adverse effects. Our team published a prospective study on the use of HOT in dyspneic dogs, showing a significant increase in PaO2 and SpO2 with HOT compared to nasal oxygen therapy. Tolerance was excellent9.

Usual flow rate for conventional oxygen therapy is 150 ml/kg/min for nasal cannula (e.g. 1,5 L/min for a 10 kg dog). With HOT, the flow rate is based on the patient minute ventilation (MV = respiratory rate multiplied by tidal volume (10-15 ml/kg)). So, for our 10 kg dog, with a RR of 20 bpm, the initial flow rate will be of 20 L/min, more than 10 times the flow rate of COT! Jagodish et al. recommended in their study the use of 1-2 L/kg as a flow rate9. the flow rate could be slightly adjusted based on the patient comfort. With this flow rate, FIO2 can be precisely determined. Usually, FIO2 is started at 100%, then oxygen is mixed with air to decrease FIO2 and avoid oxygen toxicity.

Conclusion: Prompt recognition of hypoxemia and institution of oxygen therapy is important in correcting tissue hypoxia. Equally important is recognizing the need for escalation of oxygen therapy in patients not responding to conventional oxygen delivery methods. In veterinary patients, intubation is associated with higher morbidity and mortality. High flow oxygen therapy is a new and promising advanced oxygen therapy technique.

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