Mechanical ventilation can be provided for small animal patients in need and requires a great deal of nursing care knowledge from the technician staff. From equipment set up and maintenance to intensive patient monitoring and diagnostic interpretation, mechanical ventilation is challenging and rewarding for the medical staff.

Mechanical ventilation is appropriate for any patient that cannot maintain minimal oxygenation and/or ventilation on their own. To determine if a patient needs assistance, a blood gas is drawn. Blood gas results will tell the patient’s acid/base status, and, if arterial blood is used, will give valuable respiratory information. CO₂, when combined with water in the presence of carbonic anhydrase, will create an acid and therefore change the patient’s pH. The body needs the pH to stay within a narrow range, and respiratory disease and malfunction can cause CO₂ abnormalities and pH changes. Understanding the finer points of acid/base status is outside the scope of this lecture; we will focus on the respiratory information from arterial blood gas.

PaO₂ is measuring the oxygen in arterial blood. It is a measurement of pulmonary function and the perfusion status of the patient. Abnormally low readings can be the result of not enough oxygen being taken in (anesthesia equipment problem, smoke inhalation, etc.), hypoventilation, ventilation/perfusion mismatch (like pneumonia), a diffusion impairment (like metastasis to the lungs), and low cardiac output.

Look at the PaO₂ and CO₂ numbers in relation to each other. Is the animal breathing faster (lower CO₂) to compensate for low PaO₂? Some use the “rule of 60” used for determining when an animal needs ventilator support—if the PaO₂ is <60 and the PaCO₂ is >60 then it may be ventilator time.

By calculating the A-a gradient, we can look deeper into the cause of the hypoxia. Is it lung disease or hypoventilation? Capital “A” is the alveolar measurement of oxygen, and the lowercase “a” is the arterial concentration of oxygen. The PaO₂ is the arterial measurement, so we need to calculate the alveolar (A) concentration. This is most useful when the FiO₂ is 0.21 (room air). Here’s the formula for calculating alveolar oxygen concentration: $A = [\text{FiO}_2 \times (Pb - Ph_{20})] - (\text{PaCO}_2/0.8)$

Pb is barometric pressure which will be a constant at sea level (760). Ph₂₀ is saturated water vapor pressure which is 50 (sources vary on the exact number). The 0.8 is the respiratory quotient and is a fixed number. At sea level and breathing room air we can simplify the equation to: $A = 150 - (\text{PaCO}_2/0.8)$

Normal A-a gradient should be less than 15. If the result is greater than 25, we can assume that the patient’s hypoxia is due to significant pulmonary parenchymal disease or heart disease.

Lastly, when the animal is receiving supplemental oxygen (and the arterial sample was drawn with the patient on oxygen), you need to calculate the PaO₂:FiO₂ ratio. This will tell you if the patient is responding appropriately to the amount of oxygen it’s receiving. The PaO₂ should be five times the FiO₂ (so with a FiO₂ of 21% or 0.21, the PaO₂ should be 100 or close to it). A normal PaO₂:FiO₂ ratio is 250–400. If that number is less than 200 then the patient has significant pulmonary disease and possible acute respiratory distress syndrome (ARDS). This is an important number to know, as you may have a patient with a PaO₂ of 100 which looks good, until you notice that the FiO₂ is 80%. 100/0.8 = 125, which is a terrible result!

Once the decision has been made to mechanically ventilate, it is time to pull out the machine and understand the basics of ventilator settings:

- **Assist/Control:** completely generated by machine. Minimum respiratory rate (RR) set. Sensitivity can allow patient to increase rate, but all breaths full breaths (controlled by machine)
- **Volume controlled:** set tidal volume, airway pressure varies
- **Pressure controlled:** set peak inspiratory pressure (PIP), tidal volume varies
- **Synchronized intermittent mechanical ventilation (SIMV):** ventilator set to minimum breaths, patient can breathe as much as they want in between. Machine tries to synchronize. Weaning mode
- **Continuous positive airway pressure (CPAP):** All breaths are patient triggered, always positive airway pressure set (decreases resistance, increases compliance)
• Tidal volume: 10–15ml/kg normal; diseased patients may be 6–8ml/kg. Start at 10 and move up
• Peak inspiratory pressure (PIP) normal 8–15cm/H2O; diseased lungs stiffer—may need higher to achieve TV
• Positive end expiratory pressure (PEEP)—2cm/H2O to start, increase as needed—higher with worse lung disease
• Inspiratory to Expiratory Ratio (I:E ratio) must be closely watched. 1:2 is normal, which means exhalation takes twice as long as inhalation. The ventilator needs to allow full exhale before another inspiration. High RR can lead to breath stacking (not fully exhaling before inhaling) and intrinsic PEEP
• Start with 100% FiO2

Ventilator settings will change frequently at the start of mechanical ventilation and the technician must be aware of changes to track them and monitor patient response. While monitoring a patient on the ventilator, technicians must be aware of the complications and be ready to assist the patient, and anticipate problems. Complications include:

• Positive pressure ventilation will increase intrathoracic pressure, which may decrease venous return causing hypotension. Monitor blood pressure and heart rate closely.
• Ventilator-associated pneumonia is a common finding in these patients. Their immune system is taxed with their illness and the ventilator requires invasive procedures. Practice good aseptic nursing care; use sterile gloves when appropriate and exam gloves at all other times.
• Ventilator-induced lung injury can result from PIP too high or not enough PEEP. Choose settings carefully and adjust as needed according to patient monitoring.
• Oxygen toxicity can occur at 100% FiO2 for <12hrs; long term goal should be <60% FiO2.
• Pneumothorax can result, especially in trauma patients or badly diseased lungs. Keep this complication at top of mind when problems occur.
• Is your patient bucking the vent? Examine them for:
  o Hypoxemia—check machine, tube obstruction, pneumothorax?
  o Hypercapnia—check machine, tube obstruction, pneumothorax?
  o Pneumothorax—dramatic drop in SpO2 with dramatic increase in ETCO2
  o Hyperthermia—anything >102°F can cause panting
  o Inadequate machine settings
  o Inadequate anesthesia

While learning the ins and outs of your ventilator is important, the nursing care of the mechanically ventilated patient takes time, energy, and all of your combined knowledge in order to be successful. Understanding the disease process and what to watch and prepare for, understanding various drug classes and how they interact with each other and the patient, the special needs of an intubated patient anesthetized for days at a time, and the care of advanced tubes all fall to the technician to comprehend.

All patients will need a multi-lumen central line, two peripheral IV catheters, an indwelling urinary catheter, and an arterial catheter. In many instances, it will be easier for the staff and the patient to place many of these after the animal is anesthetized and ventilated, but placement will need to happen quickly after initiating mechanical ventilation. Depending on the patient and hospital, the animal may be placed on one or more of the following medications to remain anesthetized for the duration of ventilation. It is important that the technician understand compatibility of these different drugs as well as the dose dependent side effects and monitor appropriately.

• Fentanyl constant rate infusion (CRI): strong opioid, cardiovascular sparing, can be titrated to keep patient anesthetized and comfortable, allows for more smooth wake up.
• Ketamine CRI: easily titrated, helps with keeping patient anesthetized.
• Propofol CRI: Propofol administered as a CRI can keep patients anesthetized while on the ventilator. It is important to monitor blood pressure as propofol is a vasodilator. Bolus amounts can be given as needed. Propofol metabolizes quickly and using it alone can make for a rough weaning process.
• Atracurium CRI: Atracurium is a muscle paralytic. For ventilated patients, we usually administer atracurium in a CRI, but can also give small boluses as needed for patient comfort. It has little effect on the cardiovascular system except slightly raising the heart rate and a relatively short duration of action.
• Midazolam CRI is sometimes combined with fentanyl and/or ketamine to provide analgesia and sedation.
Dexmedetomidine CRI may be used to in combination to keep the patient anesthetized for ventilation.

Along with monitoring the ventilator settings and drugs, mechanically ventilated patients are anesthetized for possibly days at a time and need close one-on-one care from the technician staff. Special ventilator flow sheets can make keeping track of duties easier and ensure no tasks are skipped.

Full vital signs should be measured and recorded every hour including body temperature, heart rate and ECG, pulse quality, respiratory rate and any effort against the ventilator, mucous membrane color, capillary refill time (CRT), blood pressure (indirect, direct if possible via the arterial catheter), SpO2, and ETCO2. The use of a multi-parameter anesthesia monitor is ideal with these patients.

IV catheters, both peripheral and central, need standard catheter care. Unused ports should be flushed with saline at least every four hours and catheter insertion sites monitored for signs on infection. Bandages and wraps must be changed if they become contaminated, and central line wraps changed daily. Arterial catheters must be flushed with saline every hour to keep them patent. If direct pressure monitoring is possible, this will help maintain arterial catheter patency. Urinary catheter maintenance should occur on an ongoing basis, watching for any contamination and cleaning according to hospital policy.

Proper airway management must be observed in these patients. Pressure necrosis of the trachea can occur if the endotracheal or tracheostomy tube is left static for multiple days. Every four hours the cuff is deflated, the tube advanced or extracted a small amount, and then re-secured. Ensure proper technique for cuff inflation is used. Ventilator patients may also need frequent suctioning of their endotracheal/tracheostomy tube to prevent clogging. In some patients, every four hours is sufficient, but more often may be required. To suction:

- Pre-oxygenate the patient at 100% FiO2 for one minute
- Disconnect the patient from the ventilator
- Using sterile gloves, insert a sterile suction catheter into the endotracheal tube and feed the catheter about 1cm past the distal end of the endotracheal tube
- Begin suction, rotating the suction catheter and suction as you remove the catheter from the tube
- Remember the patient is not breathing while you suction; if necessary, place the patient back on the ventilator for a minute before disconnecting and repeating the suction process
- Once completed, reconnect the patient to the ventilator at 100% FiO2 for one minute, then return to previous settings

The airway tube is also changed on a regular basis and the length of time between changes is determined by the patient. Some may need a clean tube every four or eight hours, many can go 12–24 hours between changes. Before changing out the endotracheal or tracheostomy tube, have all equipment ready before disconnecting the patient from the ventilator to ensure a smooth procedure and return to mechanical ventilation. Patient should be pre-oxygenated at 100% FiO2 before changing out equipment.

Oral care is vital to proper ventilator patient care. Bacteria will easily colonize in the mouth when the tissues dry out due to general anesthesia, cessation of swallowing, and higher than normal airflow through the mouth because it is open all of the time. Every four hours, wearing exam gloves, the technician must gently rinse and swab out the oral cavity using 0.02% chlorhexidine or a veterinary oral rinse. If this bacteria is not kept under control, it can be transported into the lungs via the endotracheal tube (when it is changed out) and contribute to pneumonia. Clean the pharyngeal area and the entire mouth and tongue of any mucus and keep the mouth moist to keep the tissues healthy. Keep the tongue moistened and move the SpO2 probe frequently. When the mouth is cleaned, the eyes should be cleaned and lubricated as well.

Patients on mechanical ventilation benefit from some form of physical therapy. They are anesthetized for days at a time and will develop peripheral edema from lack of movement. Patients that are minimally anesthetized may find range of motion exercises too stimulating, but performing limb massage every two to four hours is still beneficial. Ventilator patients should be maintained in sternal recumbency when possible to allow for proper lung inflation, but pay attention to their hind end and rotate their hips every four hours to reduce edema and pressure sores. Change bedding as it becomes soiled and make sure pressure points are properly padded.
As far as the ventilator itself, check the settings often and record the settings every four hours or when changes occur. It is important to be able to look back and know which changes had the best impact on the patient. Create a blood gas flow sheet to track changes in results to track progress. Check the ventilator hoses often, as condensation builds quickly and can cause alarms to sound. Empty the tubes as needed and change them out if they become occluded with patient discharge. Check the humidifier to ensure it stays full. Be familiar with alarm settings and what to do in case of emergency. Keep emergency materials (laryngoscope, endotracheal [ET tube], ambu-bag) close to the patient so you can hand ventilate in case of mechanical failure.

Ventilator patients require close monitoring, a great deal of knowledge, and intensive nursing care, but allow the medical team to work together for an ideal outcome.

Questions

1. How will hypoventilation affect a patient’s pH?
   a. Have no effect
   b. Increase the pH
   c. Allow the pH to stay within the normal range
   d. Decrease the pH

2. Which of the following is an appropriate Pa02:Fi02?
   a. 90
   b. 100
   c. 200
   d. 300

3. Positive pressure ventilation can cause an increased intrathoracic pressure leading to
   a. Hyperventilation
   b. Hyperthermia
   c. Hypocapnia
   d. Hypotension

4. Which of the following patient treatments must be performed every four hours on a patient being mechanically ventilated?
   a. Oral care
   b. Airway tube cuff deflated and tube position moved
   c. Unused IV catheters flushed with saline
   d. All of the above

5. A constant amount of pressure left in the lungs after exhalation describes
   a. PIP
   b. Tidal Volume
   c. I:E Ratio
   d. PEEP

Recommended Reading