MECHANICAL VENTILATION IN SMALL ANIMAL PATIENTS: THE INS AND OUTS
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Key Points:
1. Ventilatory support during general anesthesia can improve alveolar ventilation and oxygenation in addition to reducing a patient’s work of breathing and ensuring adequate delivery of inhalant anesthetics.
2. Mechanical ventilators used in conjunction with anesthetic agent delivery systems are classified as volume and/or pressure limited. Continuous positive pressure ventilation is the most frequently applied mode of ventilatory support during general anesthesia.
3. Ventilatory support has both beneficial and deleterious respiratory and cardiovascular consequences. Prolonged inspiratory times and high mean/peak inspiratory pressures reduce venous return, cardiac output and systemic arterial pressure while increasing the potential for pulmonary barotrauma or volutrauma.
4. The most frequent technical difficulties associated with mechanical ventilatory support are due to leaks in the system, excessive delivery of tidal volume and malfunctioning relief valves.

The indications for ventilatory support can be considered as either primarily patient or procedural driven. Patient related factors that result in the need for ventilatory support include apnea, hypoventilation, hypoxemia, and excessive work of breathing. General anesthetics, opioid analgesics and sedatives all contribute to central respiratory depression and as a consequence, result in an increase in alveolar and arterial carbon dioxide. While a mild increase in arterial carbon dioxide levels are not harmful in normal patients, moderate to severe hypercapnia can result in acidemia, and signs of excessive sympathetic stimulation (high heart rate and systemic arterial pressures). The impact of hypoventilation on a patient’s oxygenation is heavily dependent on their inspired oxygen fraction, with the greatest negative impact occurring in patient’s breathing room air. Hypoxemia can occur independent of hypoventilation as well, and certain ventilatory strategies can be used to improve a patient’s oxygenation by minimizing atelectasis and ventilation-perfusion mismatching within the lung. A narrowed air diameter, poor chest wall (obesity) or diaphragmatic (increased abdominal pressure) compliance and position can dramatically increase a patient’s work of breathing and contribute to significant hypoventilation. Procedurally, thoracotomy and the use of muscle paralytics are absolute indications for ventilatory support while laparoscopy is likely to sufficiently impair adequate ventilation that ventilatory support results in improved patient cardiopulmonary stability.

Ventilators can be designed as self-contained units or as components designed to integrate with an anesthetic machine. The former tend to be very sophisticated with many ventilatory mode options, the potential to humidify the inspired gases and alter the inspired oxygen fraction. These properties make them suitable for use in an intensive care setting where patients have primary pulmonary dysfunction or have the need for long-term ventilatory support. These ventilators can however be used with injectable...
anesthetic maintenance regimes during surgery if required for either the procedure or if the patient’s status warrants the continued delivery of a specific ventilatory strategy. Ventilators suitable for integration with an anesthetic machine can be designed as part of the anesthetic machine or as a physically separate unit. The latter offer greater flexibility however they are more cumbersome if mobility within a clinic is required. Anesthesia ventilators are generally classified on the basis of the major control variable as either pressure or volume targeted ventilators. Other important characteristics of a ventilator include the power source, drive mechanism, cycling mechanism and bellows type. While critical care ventilators have the potential to offer many different ventilatory modes such as continuous positive airway pressure or pressure support ventilation, anesthesia ventilators are primarily limited to continuous positive pressure ventilation.

While providing ventilatory support can improve alveolar ventilation, oxygenation and the consistency in delivery of inhalant anesthetics, the institution of positive pressure ventilation has profound effects on the cardiovascular system. Specifically, positive pressure ventilation can result in a decrease in cardiac output, systemic arterial pressure and overall oxygen delivery. The magnitude of these changes is dependent on the ventilatory strategy used and the patient’s hemodynamic status. Monitoring the patient’s blood pressure and depth of anesthesia are crucial when instituting ventilatory support as profound hemodynamic changes can occur rapidly. Healthy small animal patients are relatively resistant to primary ventilatory induced lung injury, however, in a patient with lung injury, positive pressure ventilation strategies can contribute to the progression of disease. The inclusion of positive end expiratory pressure and the use of a low tidal volume strategy can minimize the progression of injury however the patient should be transferred to a critical care ventilator at the earliest opportunity.

Understanding how a mechanical ventilator functions is crucial as ventilator malfunctions can occur. Typical ventilator malfunctions include leaks, bellows malfunctions, and occluded relief valves. The latter can result in lethal airway pressures within minutes. Monitoring circuit pressures and the patient’s expired carbon dioxide waveform and hemoglobin saturation continuously greatly improves the safety of ventilatory support.

References: