During intrathoracic surgery the negative pressure that normally exists in the thoracic cavity and is necessary for lung expansion is disrupted by surgery. Therefore, these patients need to be provided with positive pressure ventilation. This can be done manually, which can be very labor intensive for the anesthetist, or by the use of a mechanical ventilator, which is recommended. Usually normal tidal volumes of 15-20 mls/kg are acceptable. Peak inspiratory pressure (PIP) is normally limited to 15-20 cm H₂O. In some cases where there is significant pressure on the diaphragm from enlarged abdominal organs or in the case of a diaphragmatic hernia, higher pressures may be needed to deliver adequate tidal volumes. Respiratory rates of 8-12 breaths per minute as usually adequate. It is important to maintain adequate tidal volumes to help prevent atelectasis. The use of capnography to monitor the adequacy of ventilation is ideal. ETCO₂ levels should be maintained at 35-45 mm Hg.

Thoracotomy patients will often de-saturate at some point during the procedure so a plan for dealing with this complication should be made. Desaturation can occur at any time during surgery but can often occur just after induction during the surgical prep depending on the lesion and the condition of the patient. If it is a case of pneumo/chylo/hemo thorax, a thoracocentesis or aspiration of existing chest tubes usually helps saturation return to acceptable levels. If possible, the affected side of the chest should be put down. Ideally respiratory compromised patients should be placed in sternal recumbency but this is also not practical for surgery. Very often turning a patient onto its back for surgical prep can have catastrophic results. Patients can actually arrest when they are flipped into dorsal. If at all possible, prep these patients “side to side,” build an incline on the surgery table so that the head remains higher than the tail. The use of positive end expiratory pressure (PEEP) can be extremely helpful in treating desaturation during surgery. PEEP can be applied manually or with PEEP valves which are commercially available in various sizes.

Monitoring ventilation on thoracotomy patients under anesthesia can be done a number of ways. Ventilation is assessed in terms of rate, rhythm, and tidal volume. First of all, a good look at the patient’s chest excursions should be done to evaluate for quality and effort. Auscultation of the lungs should be performed prior to sedating or anesthetizing any patient. Normal lung sounds should be heard on both sides of the chest. Any abnormal sounds should be investigated prior to moving forward with anesthesia as anesthetic drugs can depress respiration and ventilation and may worsen existing problems.

Mucous membrane color should be assessed regularly. The tongue and gums should be pink. Any change in color, especially blue or purple tingeing can indicate hypoxemia.

Respirometers can be used to measure tidal volume and minute volume. Expired gas passes through oblique slits, which creates circular gas flow in a chamber, causing rotation of a double-vaned rotor. The rotor is coupled via a set of linkage gears to a display indicator dial and needle. Accumulated minute volume is recorded and each breath’s tidal volume can be viewed. The respirometer measures volume in one direction only. Flow can be calculated by averaging recorded volumes over time. Respirometers may be especially helpful during recovery to ensure that the patient is ventilating well enough to be removed from support. Apnea or respiratory monitors detect the movement of gas through the proximal end of the endotracheal tube. They
provide no information on tidal volume or the physiologic state of the patient. They can be falsely activated by pressure on the chest or abdomen of the patient or by cardiac oscillations that cause gas movement in the trachea.

Pulse oximetry is a simple non-invasive method of monitoring the percentage of hemoglobin which is saturated with oxygen. The pulse oximeter consists of a probe attached to the patient (usually lingually in veterinary medicine although many other sites work well) which is linked to a computerized unit. The unit displays the percentage of hemoglobin saturated with oxygen together with an audible signal for each pulse beat, a calculated heart rate and in some models, a graphical display of the blood flow past the probe. An oximeter detects hypoxia before the patient becomes clinically cyanotic. A source of light originates from the probe at two wavelengths. The light is partly absorbed by hemoglobin, by amounts which differ depending on whether it is saturated or desaturated with oxygen. By calculating the absorption at the two wavelengths the processor can compute the proportion of hemoglobin which is oxygenated (SpO2). The oximeter is dependant on a pulsatile flow and produces a graph of the quality of the flow. Any reduction in pulsatile flow produced by vasoconstriction, hypovolemia, severe hypotension, hypothermia, and some cardiac arrhythmias will result in an inadequate signal for analysis. Sometimes moving the probe to a new location will work. The probe can cause constriction of the vessels beneath it over time. Bright ambient light can affect the signal as well. Movement artifact is a problem for the pulse oximeter. This comes mostly into play during recovery when patients begin shivering or gaining control of their tongues. The oxygen saturation should always be above 95%. Slight changes over time may just mean the probe needs to be repositioned, but the overall patient should be assessed for desaturation, especially in a thoracotomy patient where desaturation is likely. Sudden steady decreases should be investigated immediately and supportive measures taken. In the thoracotomy patient it is often advantageous to remove the patient from the ventilator and commence “hand bagging” instead. Hand bagging allows for more control of tidal volumes and positive end expiratory pressure which can assist in improving saturation.

Capnography measures the carbon dioxide concentration in expired gas. It provides a non-invasive means of measuring arterial carbon dioxide pressure (PaCO2). At the end of expiration, assuming there is no rebreathing, the airway and the lungs are filled with carbon dioxide free gases. Carbon dioxide diffuses into the alveoli and equilibrates with the end-alveolar capillary blood. As the patient exhales, a carbon dioxide sensor at the end of the endotracheal tube (if there is one) will detect no carbon dioxide as the initial gas sampled will be the dead space gas. As exhalation continues, carbon dioxide concentration rises gradually and reaches a peak as the carbon dioxide rich gas from the alveoli make their way to the sensor. At the end of exhalation, the carbon dioxide concentration decreases to zero (base line) as the patient commences inhalation of the carbon dioxide free gases. The number given on the capnograph is called the end tidal CO2 (ETCO2). The ETCO2 value is approximately 5-10 mm Hg less than the PaCO2 of the patient with normal pulmonary function. The evolution of the carbon dioxide from the alveoli to the sensor during exhalation, and inhalation of carbon dioxide free gases during inspiration gives the characteristic shape to the carbon dioxide curve on the capnograph and is identical in every animal. Any deviation from this identical shape should be investigated to determine a physiological or pathological cause producing the abnormality. A report of inspired carbon dioxide (graph not returning to baseline-zero) on the monitor means rebreathing of CO2 is occurring and can indicate equipment problems such as expired soda sorb or a malfunction in the valves of the anesthetic machine. Excessive dead space can also be a cause. Abnormal
shapes on the capnograph can be caused by a number of things and can be interpreted if normal wave physiology is understood. The beginning of exhalation should be the baseline. The upswing represents the variable emptying of alveoli (airway disease will flatten out the slope). The plateau reflects alveolar gas. The down slope represents inspiration. Rebreathing will make the down slope less steep. If there is no wave form, it means the patient is apneic for some reason. If the baseline is increased it represents rebreathing malfunction. An increased plateau is representative of hypoventilation or increased rate of carbon dioxide production. A decreased plateau to a new stable level indicates hyperventilation, hypothermia, airway leaks, tachypnea, or a calibration error. An abrupt drop to zero means an airway obstruction, disconnect, apnea or cardiac arrest. An unstable, fluctuating plateau represents patient “bucking” the ventilator. Normal CO2 is 35-45 mm Hg. Low CO2 can indicate over ventilation or very poor perfusion. Determining the cause will help determine treatment. High carbon dioxide (hypercarbia) can indicate hypo-ventilation, airway disease or obstruction or anesthetic machine malfunction.

Capnography is easy to use and non-invasive. It provides a continuous measurement of end tidal carbon dioxide. It provides information on the adequacy of ventilation, airway obstruction, disconnection from the breathing system and severe circulatory problems.

The analysis of carbon dioxide and oxygen tensions in an arterial blood sample provides very useful information on pulmonary function during surgery. Most analyzers also provide acid-base status and some electrolyte values as well which can be good information to have during complex surgeries. There are now many different bedside portable blood gas units available, although expense will limit their availability in general practice. Blood gas samples are drawn from an artery, either directly or through an arterial catheter into a heparinized syringe. Care must be taken to make sure that the sample is not exposed to room air or drawn into a syringe with excessive heparin in it as this can affect results. Most blood gas analyzers will measure or calculate PaO2, PaCO2, pH, BE, HCO3-, k+, Na+, and perhaps other electrolytes.

In animals breathing room air and with normal lung function, PaO2 should be 80-85 mm Hg. Numbers below this can indicate hypoxemia. Increases in inspired oxygen lead to increases in PaO2. As a general rule, PaO2 should be 5 times the inspired oxygen concentration. Therefore, an animal on 100% oxygen should have a PaO2 of greater than 500 mm Hg.

Positive pressure ventilation (PPV) is indicated when the thoracic cavity is opened during thoracotomy surgery. A major contraindication for positive pressure ventilation is a closed pneumothorax, as positive pressure ventilation will make it worse. Positive pressure ventilation can decrease arterial blood pressure and reduce cardiac output especially if airway pressures are consistently more than 10 mm Hg or if circulating blood volume is low. Artificial ventilation decreases pulmonary blood flow, and therefore may lead to ventilation-perfusion abnormalities. Circulatory changes during positive pressure ventilation are caused by prolonged increases in mean airway pressures and decreases in CO2.

Often recovery is the most difficult period to manage in thoracic surgery patients. During anesthesia the patient is intubated, ventilated and provided with 100% oxygen. All body systems are being supported under anesthesia. A plan for post operative analgesia should be in place. Thoracotomies are considered highly painful surgeries and analgesics are essential to promote adequate ventilation and chest excursions in the post-operative period. Patients with inadequate pain relief are at risk of hypoventilation due to small tidal volumes (breathing hurts). Respiratory depression from opioid administration is always a concern, but they should not be withheld and the drugs can be titrated to effect and antagonized if necessary. The partial agonist opioid
buprenorphine may cause less respiratory depression but is likely not a potent enough analgesic for immediate post-op relief of thoracotomy patients. Local analgesia techniques are a great adjunct to systemic analgesics in this patient group. Local and regional analgesia allow for lower doses of the systemic analgesics to be used and therefore also decrease the side effects. A very effective local anesthesia technique involves the use of a wound soaker or diffusion catheter placed into the wound/incision.

After weaning from the ventilator and discontinuing anesthesia, the patient will need to be closely monitored to see if it can be weaned from oxygen support. The pulse oximeter should be monitored, along with mucous membrane color as an oxygen withdrawal test is done. If the patient cannot tolerate being off of oxygen, desaturation will occur within about a minute. Sometimes these patients just need time to recover a bit more, sometimes they need ongoing oxygen support in the form of nasal O2 lines or an oxygen cage. These cases often require a great deal of the anesthetist’s time and patience in recovery. Extubating these patients should be done as late as possible unless the patient is a cat and prone to laryngospasm. Although usually rare, be prepared to re-anesthetize and re-intubate if needed. Having a clean ET tube, a laryngoscope and a little induction agent nearby is good planning. Patients should be recovered in sternal position to maximize lung inflation of both lung fields. The head may be supported with a pillow or rolled towels. Once the patient is extubated, pulse oximetry monitoring should continue. Once patients are alert and moving this can be difficult, but if a toe or ear or some other remote area doesn’t work, monitor by mucous membrane color, feel for air movement at the nostrils, listen for obstructive sounds and monitor chest excursions. The experienced anesthetist will know right away whether the patient is going to tolerate being extubated and off of oxygen.

Some patients with extreme trauma, severe complications during surgery, or very radical surgeries may need to be placed on ongoing ventilator support in the ICU if they cannot be successfully weaned from the surgery ventilator.

In any anesthesia case, being prepared and planning for complications can help ensure a successful anesthetic event, even in a challenging thoracotomy patient.

References: