**Key Points**

- Pulmonary surgery is readily performed using thoracoscopy; however, conversion to the open approach may be required and equipment for doing so should be available in the operative suite.
- Minimally invasive surgery (MIS) of the lungs is one of the rare procedures that may require one lung ventilation (OLV), the consequences of which are known and must controlled for during surgery.
- MIS is useful in the diagnosis and treatment of neoplasia, pyothorax, and spontaneous pneumothorax. Treatment of lung lobe torsion would likely be challenging using MIS.
- MIS pulmonary procedures include biopsy (including lymph nodes and pleura for the diagnosis and staging of cancer) and partial and complete pneumolobectomy.

Minimally invasive surgery (MIS) of the chest of small animal patients has greatly expanded in the past decade. Many different procedures from diagnostic to therapeutic have been developed and are becoming the standard of care in veterinary medicine. Pulmonary surgery has been more recently developed due to the difficulty in working with the fragile parenchyma. As advanced therapies have been developed, more equipment has been "borrowed" from human medicine. Simple pieces, such as pre-made loop ligatures, are useful, but vessel sealing devices and endoscopic staplers have allowed for the rapid expansion of techniques. Veterinarians should realize, however, that the advancement in equipment does not replace the need for training and experience in thoracic surgery. Complications or inability to visualize the thoracic structures necessitate conversion to an open approach, so intercostal thoracotomy and median sternotomy should be quite familiar to and doable by the surgeon performing MIS of the lungs.

Concurrent ability to perform one lung ventilation (OLV) and evaluate for and address its consequences are also required when performing advanced pulmonary procedures, specifically complete pneumolobectomy. A flexible endoscope is required to establish and confirm the lung that will be ventilated, rapid atelectasis is also easily seen during thoracoscopy. Thoracoscopic assessment of the extent of atelectasis is important; insertion of the bronchial tube too far distally can result in severe hypoventilation obtained when only the caudal lobe is ventilated. The tube should be withdrawn until the entire side of the lung is ventilated.

One lung ventilation may be accomplished using specifically designed endotracheal tubes. The tubes usually include a bronchial cuff and tracheal cuff. Specialized tubes allow for alternating OLV by changing the lumen that is ventilated. Simple techniques for OLV involve passing a bronchial blocker alone and using a standard endotracheal tube. Alternating the lung ventilated with the last method is not possible without changing the position of the bronchial blocker. Regardless of the technique chosen for providing OLV, OLV is best established with the patient in the operative suite positioned for surgery. Loss of OLV is frustrating and occurs most often during transportation of the patient. Tidal volume should be decreased by ½ and ventilatory rate doubled to maintain minute volume. These initial changes will not be the final ones made, changes in ventilatory status will necessitate further changes in ventilator settings.
The changes associated with OLV include increased shunting, decreased PaO₂, decreased SaO₂, increased P A-aO₂, increased PaCO₂, and increased cardiac index as well as mean arterial pressure, diastolic arterial pressure, and heart rate. The changes may not be clinically significant in experimental dogs, and probably are mitigated by hypoxic pulmonary vasoconstriction. Clinical patients undergoing MIS for pulmonary surgery will likely have more significant alterations. The changes can be overcome using positive end expiratory pressure (PEEP) or continuous positive airway pressure (CPAP). These changes require mechanical ventilation and close monitoring of pulse oximetry, end tidal CO₂, direct blood pressure, and arterial blood gas. Alterations in tidal volume and ventilatory rate should be done per the patient's needs, and cessation of OLV should be done as soon as possible.

The conditions that may require pulmonary surgery include chronic respiratory disease, neoplasia, pyothorax, and spontaneous pneumothorax. Chronic cough and/or ventilatory compromise undiagnosed via thoracic radiography, computed tomography, and pulmonary fine needle aspirate may require MIS for thoracic exploration and pulmonary biopsy. Diffuse disease of the lung is readily visible as generalized abnormal color and texture of the lung and the lungs frequently do not collapse to the extent and color of that of normal atelectic lung. Known pulmonary mass lesions can be investigated for removal via partial or complete pneumolobectomy. Concurrent hilar lymph node and pleural biopsy should be considered; lymph node biopsy is crucial for staging and prognostication of primary lung tumors; however, metastatectomy can also be done thorascopically. Even very small lymph nodes can be seen and removed with the lighting and magnification provided by MIS. Thorascoscopic partial or complete pneumolobectomy may be preferable to an open approach for metastatic lesions, as it should be associated with less morbidity than an open approach, which is of valuable for patients with advanced neoplastic disease. Thoracic debridement for pyothorax rarely involves lung, but MIS would be a potential addition to the treatment of this condition. Severe or numerous adhesions make visualization and progress difficult during MIS and are an indication for conversion to an open approach, however. Cases of spontaneous pneumothorax are now being evaluated routinely with MIS. Both hemithoraces of the patient can be examined for lesion localization prior to removal via partial or complete pneumolobectomy. Remember that any abnormal tissue should be removed from the chest using a specimen bag to theoretically reduce the risk of port site metastasis.

Simple biopsy for diffuse lung disease can be easily achieved using a pre-tied loop ligature. Choose a segment of lung for sampling, and insert the ligature into the thorax adjacent to the site. Pass grasping forceps through the same port and through the loop and lift the lung through the ligature. Tighten the loop, and excise the portion of lung, then transect the long side of the suture connected to the loop. Evaluate the stump for hemorrhage and air leakage prior to closure. This method of sampling is best reserved for collection of no more than 2 cm of the tip of a lung lobe. Large samples are best procured with thorascopic-assisted techniques or endosurgical stapling devices.

Thorascoscopic-assisted partial pneumolobectomy can be done following thorascoscopic exploration and procurement of lymph node samples as required by the patient. Once the abnormal lung is identified, lengthen a port site adjacent to the affected lobe. Do not retract the ribs so as to avoid postoperative morbidity. Once the lung is exteriorized, excise it with standard techniques such as stapling or suture placement. Check the site for hemorrhage and air leakage both before and after returning the lung to the thoracic cavity.
The most challenging technique of MIS pulmonary surgery is complete pneumolobectomy. It requires OLV and endосurgical stapling devices. Completely explore the thorax and sample hilar lymph nodes as necessary. Caudal lung lobes must be freed of their dorsal mediastinal attachment before passing an endoscopic GIA stapler across the pulmonary hilus. The EndoGIA requires a large port or mini-thoracotomy for insertion into the chest. The stapler has lines to demark the site of staples and transection. Be sure that the entire hilus is incorporated within the lines on the stapler prior to closure of the stapler. Using the longest available cartridges is strongly recommended to avoid multiple passages, repeated trauma, and lack of complete occlusion of the hilar structures. Advance the trigger and transect the pulmonary hilus. Immediately evaluate for hemorrhage and check to be sure the entire hilus has been stapled. If not, pass a second cartridge and staple the remainder. Evaluate the site as for open surgery, and remove the sample. The duration of surgery is not unexpectedly long (>100 min) but should decrease with experience as should complications. Complications included conversion in 4/9 to an open approach due to intercostal arterial hemorrhage, failure of OLV, and poor access to the right middle lung lobe.

The described procedures augment the use of MIS for pulmonary surgery. Care should be taken to fully evaluate the thorax and be prepared to perform an open approach on an emergent basis. Complications of thoracoscopic lung surgery include hemorrhage, not only from the lung but from the port sites as well as alterations associated with OLV, loss of OLV, and air leakage. A rare complication of pneumolobectomy was entrapment of the suture at the end of an endobronchial blocker in the stapled hilar site. The advances in thoracic MIS likely decrease the morbidity of pulmonary surgery in veterinary patients and may become standard of care in the future.