Pneumothorax

Pneumothorax by definition is the accumulation of free air or gas in the pleural space. Air may enter the pleural space from any of three sources: the lung itself via a pleuropulmonary leak; the atmosphere via a pleurocutaneous, pleuroesophageal or pleurobronchial communication; or due to the presence of gas-forming organisms in the pleural space. Pneumothorax is classified according to its etiology, pathophysiology, or the magnitude of lung collapse.

Pneumothorax may be of traumatic or spontaneous origin. Traumatic pneumothorax has been reported in 47% of all cases of chest trauma in small animals and most often is the result of automobile accidents. Spontaneous pneumothorax is defined as a closed pneumothorax in which the lung parenchyma is the source of air leakage and occurs in the absence of antecedent trauma. Spontaneous pneumothorax is further classified as primary or secondary. The term primary spontaneous pneumothorax denotes the absence of clinical evidence of pre-existing underlying pulmonary disease. Secondary spontaneous pneumothorax describes a clinically recognizable coexisting structural or functional abnormality in the lung. All cases of secondary spontaneous pneumothorax occur as the result of some underlying pulmonary disease process.

Pathophysiology

When air enters the pleural space, it separates the visceral and parietal pleura and results in both collapse of the lung and expansion of the thorax. When the mediastinum is intact the pneumothorax is unilateral, if it is disrupted the pneumothorax may be bilateral. Air may
continue to accumulate in the pleural space even after one lung has completely collapsed, resulting in a volume of trapped air which is greater than the volume of affected hemithorax. The patient may develop a positive intrapleural pressure during expiration and occasionally during inspiration. This is known as a tension pneumothorax and is an immediately life-threatening situation. A tension pneumothorax develops when a one-way valve effect occurs in which air enters the pleural space (during inspiration) but cannot escape.

Clinical Signs

The patient with pneumothorax has clinical signs related to inadequate ventilation, reduction of tidal volume and functional residual capacity, and resultant hypoxemia and respiratory acidosis. Tachypnea is often the first respiratory response to small volumes of free pleural air. Initially, this increased ventilation lowers the arterial carbon dioxide and raises the pH of blood. As the amount of free pleural air increases, the response progresses to hyperventilation. This reduces the physiological dead space in the lung and improves the efficiency of gas exchange. The dog can tolerate massive pneumothorax of up to two and one-half times its residual volume by increasing its chest expansion. However, as the pneumothorax progresses these compensatory mechanisms fail, arterial CO₂ rises, and severe acidosis may be fatal. The degree of functional derangement with pneumothorax depends on the degree of collapse and the lung function present before collapse. In normal individuals, pneumothoraces of 50% lung collapse may be well-tolerated, while in patients with underlying lung disease and ventilatory compromise, a small pneumothorax may evoke devastating changes in function.

Diagnosis of Pneumothorax

Classic radiographic findings of pneumothorax include: 1) increased width of an air-filled pleural space, 2) partial pulmonary collapse and retraction of lung margins from the chest wall, and 3) the heart shadow elevated off the sternum in the lateral view. With traumatic pneumothorax concurrent fluid accumulation and lung contusions are common. There may be obvious pulmonary disease in cases of secondary spontaneous pneumothorax. Parenchymal disease may be localized to one lobe as in primary lung cancer or lobar pneumonia, or it may be seen diffusely in cases of metastatic cancer, thromboembolic disease, or generalized pneumonia.

Spontaneous pneumothorax is often a more difficult diagnosis to make radiographically, as it may be present bilaterally without radiographic evidence of parenchymal disease. In humans, only 10-20% of cases will show evidence of pulmonary blebs or bullae on plain thoracic radiographs. Cavitating lesions, bullae or blebs may be visible which make further diagnostics unnecessary, but newer techniques have been described to increase the efficacy of radiographic localization of bronchopleural fistula, including the use of contrast material and scintigraphy.

Spontaneous Pneumothorax

The pathogenesis of spontaneous pneumothorax is multifactorial; many cases result from the formation of subpleural cystic spaces associated with diffuse interstitial fibrosis or emphysema. The most commonly reported concurrent condition in canine patients is chronic obstructive pulmonary disease (COPD). The leakage of trapped air through the weakened walls of dilated air spaces is probably assisted by high intrabronchial pressures during coughing. Local airway obstruction caused by mucus plugs and inflammation may also contribute. The result is pulmonary inflammation, weakening of the normal elasticity of the pleura and progressive destruction of alveolar walls leading to bullae formation. In dogs, secondary spontaneous pneumothorax has also been reported as a rare complication of bacterial or viral pneumonia, ruptured congenital cysts, and rupture of pulmonary abscesses.
formed from aspirated plant foreign bodies. Parasitic etiologies such as rupture of lung fluke or tapeworm cysts in the lungs have been described causing pneumothorax, as has pulmonary arterial thromboembolism secondary to heartworm disease. Neoplastic disease may destroy normal pulmonary parenchyma resulting in pulmonary cavitation and necrosis of visceral pleura resulting in spontaneous pneumothorax.

**Treatment of Pneumothorax**

The objective in treating pneumothorax is reexpansion of the lung to reestablish contact between the visceral and parietal pleura with the least possible morbidity. Treatment of traumatic pneumothorax depends on the degree of lung collapse, the amount of lung contusion and the clinical signs demonstrated by the animal. As a rule of thumb those cases with less than 25% estimated loss of vital capacity will not require lung re-expansion. Most cases of traumatic pneumothorax will resolve in 3-7 days without treatment. More severe cases may require O₂ therapy and placement of thoracostomy tubes with either intermittent or continuous suction.

Dogs with spontaneous pneumothorax often have significant underlying pulmonary pathology. These patients typically are presented for severe dyspnea or tachypnea. Radiographically they often demonstrate bilateral pneumothorax, and a significant number may actually have a tension pneumothorax. These patients require immediate, aggressive intervention. Often intermittent thoracocentesis will not suffice, and tube thoracostomy is recommended. Accumulation of free pleural air may be so rapid that continuous underwater suction is required to maintain ventilation. If the pneumothorax persists for more than 48 hours and clinical signs are still apparent, or if there is radiographic evidence of a source of leakage, exploratory thoracotomy is indicated. Considerable controversy exists in the veterinary literature regarding the efficacy and timing of operative intervention for spontaneous pneumothorax, however dogs that are treated surgically have lower recurrence rate and better long-term survival than those treated medically.

Surgical intervention in cases of spontaneous pneumothorax in dogs consists of exploratory thoracotomy and partial or complete resection of diseased lung tissue. Median sternotomy is the preferred approach in most cases of spontaneous pneumothorax as it allows complete inspection of both hemithoraces and gives excellent exposure to the lung apices, where the lesions are most often identified. Partial lobectomy is an acceptable alternative to complete lobectomy when the lesions are focal, as it allows preservation of maximal functional lung. Lung stapling devices¹ (TA30, TA55, TA90) have eliminated the tedious and time-consuming task of individual dissection and ligation of pulmonary vessels and bronchi. They are routinely used in these cases due to the speed and ease of application, safety and efficacy.

**Prognosis**

The prognosis for most cases of traumatic pneumothorax is good to excellent. However, due to the often generalized nature of pulmonary disease in patients diagnosed with spontaneous pneumothorax, the recurrence rate is high. However, there is a much higher incidence of recurrence in dogs treated conservatively than those treated surgically. In cases of parasitic granulomas, neoplasia, thromboembolic infarcts, pneumonia or pulmonary cysts there may only be focal involvement and resection may be curative. In cases with underlying bullous emphysema however, the prognosis is generally more guarded due to the recurrent nature of their underlying disease, and the owners of these patients should be warned early of the potential for recurrence. Yet, aggressive medical management and early surgical intervention has demonstrated the most encouraging long-term clinical results in spontaneous pneumothorax.

¹Covidien
Management of Flail Chest

Flail chest can occur when two or more adjacent ribs are fractured or dislocated both proximally and distally creating a segmental section of thoracic wall which paradoxically moves inward during inspiration and outward during expiration. The most common cause of flail chest is blunt trauma to the thorax usually secondary to an automobile accident or thoracic bite wound. Animals with flail chest injuries often arrive in a severely dyspneic state and may have other orthopedic injuries. Physiologic changes associated with flail chest include decreased vital capacity, decreased compliance, reduced functional residual capacity and increased airway resistance. These changes result in hypoventilation and a greater increase in the work expanded during breathing. Pulmonary contusions are the most common nonorthopedic lesion found in flail chest injury. Pulmonary contusions may result in hypoventilation by lowering compliance and damaged alveolar areas. Arteriovenous shunting and ventilation profusion mismatch may occur resulting in ultimate hypoxemia.

Treatment

Appropriate treatment of flail chest in small animal involves the stabilization of the chest wall. Internal fixation of the ribs has been attempted but because of pulmonary contusions presents an inappropriate anesthetic risk to many small animal patients. A viable alternative to surgical stabilization of the flail segment is the use of an external ladder splint. A splint made of aluminum rod is contoured over the dog’s dorsal thoracic and lumbar areas. The ends of the splint are then connected with horizontal bars which pass over the unstable area of the thoracic wall. The cranial and caudal aspects of the splint are padded to reduce the chance of creating pressure sores. Zero or #1 nylon or polyethylene suture material is then passed around the unstable rib segments and is secured to the horizontal bars. While passing the suture it is important to use a large curved needle and pass as close to the bone as possible to avoid puncturing of the lungs. The flail segment is then drawn outward and secured by tying the sutures around the horizontal bar. This will eliminate paradoxical movement of the chest wall. The external ladder support is usually left in place for 2-3 weeks after injury. At this time there is enough fibrous stabilization of the fracture ends to allow its removal without the reoccurrence of paradoxical thoracic movement.

TRAUMATIC DIAPHRAGMATIC HERNIA

Diaphragmatic hernias occur when a blunt force (i.e., bumper) causes a sudden increase in intra-abdominal pressure that is not simultaneously offset by an equal increase in intra-thoracic pressure. Voluntary equalization of these pressures protects the diaphragm from over-excitation. In the split second when the animal is hit by a car, the sudden increase in intra-abdominal pressure results in a diaphragmatic "blow-out", or rent. Anticipation of the trauma, giving the animal time to protect the diaphragm by closing the glottis, results in dissipation of the trans-abdominal force across the diaphragm to the major airways. This may cause bronchial or parenchymal tears that result in pneumothorax.

Diagnosis of diaphragmatic hernia in dogs occurs an average of 60-100 days after trauma. Often the initial injury results in orthopedic injuries that are treated successfully; thus, in many instances the hernia is missed by the clinician. It should be hospital policy that any small animal admitted for traumatic injury (usually hit by car) have chest radiographs to rule out thoracic trauma. Forty percent of animals with forelimb trauma and 33% of animals with rear limb injury after being hit by a car, have concomitant thoracic injury.

Hernias may occur in any area of the diaphragm but are most common in the ventral muscular region extending along the costal arch. Sometimes the diaphragm is avulsed from the costal arch. Tears ventral to the esophageal hiatus and extending to the caval hiatus are not uncommon.
Clinical signs referable to diaphragmatic hernia include rapid shallow respiration (restrictive breathing), tachypnea, cyanosis, and poor exercise tolerance. Borborygmi may be auscultated over the thorax and heart sounds may be muffled, usually unilaterally. The abdomen may appear gaunt. Chronic diaphragmatic hernias are complicated by adhesions from omentum and other herniated abdominal viscera. In addition, when liver is herniated chronically, a pleural effusion (hydrothorax) results which may also result in a restrictive breathing pattern.

Diaphragmatic hernias do not require emergency surgery in most cases. Two exceptions are herniation of the stomach into the thoracic cavity and the animal with severe dyspnea that cannot ventilate sufficiently to maintain an appropriate Po2. Remember that other problems may be causing the inability to ventilate such as concomitant pneumothorax, or severe pulmonary contusion. When the stomach herniates, the dyspnea is often accompanied by aerophagia; thus, as the stomach enlarges with trapped gas, pulmonary compliance is severely compromised. Dyspneic animals with chronic hernias and hydrothorax usually respond to tube thoracostomy prior to herniorrhaphy. Remember, many of these animals will have multiple orthopedic and soft tissue injuries; thus, they require frequent monitoring and tedious care.

Anesthetic management of an animal with a diaphragmatic hernia is essentially as for thoracotomy because when the abdominal incision is made the pleural space is open. It should be remembered that pulmonary compliance is not normal and assisted ventilation should begin as soon as the animal is induced. The inspiratory pressure required to adequately ventilate the animal will be increased in comparison to normal situations without diaphragmatic hernia. The goal when surgical repair is to be done is to get the animal into surgery and the viscera removed from the chest as soon as possible.

The best approach to diaphragmatic hernias ventral midline laparotomy. A caudal-lateral thoracotomy approach for repair of diaphragmatic hernia has been used for known unilateral hernias but it does not allow exploration of the abdomen meaning other injuries in the abdomen may be missed, and oh "what a bummer" if the wrong side is operated. The ventral midline approach provides visualization of the entire diaphragm and the rest of the abdominal viscera which may also be injured. Paracostal extension at the cranial aspect of the abdominal incision may be done to enhance exposure if necessary. Exposure of chronic diaphragmatic hernias where there are numerous intrathoracic adhesions may require caudal midline sternotomy to provide sufficient exposure to repair the defect. In some instances, the diaphragmatic rent must be enlarged to allow atraumatic return of abdominal viscera into the peritoneal cavity. Liver lobes can be devitalized after chronic herniation and resection of a liver lobe may be required. In addition, herniation of the liver may result in post hepatic bile duct obstruction and icterus.

Closure of the hernia is done with nonabsorbable monofilament nylon or polypropylene. Since the diaphragm is in constant motion because of intermittent contraction, tension on the suture line is continual. Coughing and defecation also place considerable stress on the sutures. Many suture patterns may be utilized but a simple continuous pattern is most common. The initial pattern may be oversewn for greater security.

A chest drain is placed to remove residual air from the pleural space prior to abdominal closure, and is removed after a negative pleural pressure is assured, usually the next morning. Postoperatively most diaphragmatic hernia patients recover well however some animals with chronic diaphragmatic hernias develop acute severe pulmonary edema soon after repair. This is sometimes referred to as post-expansion pulmonary edema and is thought to result from mechanical damage to the capilloalveolar membrane during reexpansion and from superoxide radical production in reperfused regions of the lung resulting in membrane damage. Empirical attempts to decrease the chance of this
complication involve leaving the lungs partially collapsed (yet adequately ventilating) and gradual removal of air or fluid from the pleural space over 1 to 2 days. Despite these attempts post-expansion pulmonary edema is frequently fatal.

Another potential problem seen in chronic diaphragmatic hernias is “loss of domain” and compartmentalization syndrome. With this condition the surgeon has difficulty closing the abdomen. The abdominal wall has contracted and stuffing the viscera into the abdomen creates increased intra-abdominal pressure postoperatively which may lead to hypotensive shock and multiple organ failure postoperatively. Sometimes making fasciotomy incisions in the abdominal wall is necessary to relieve the pressure and salvage the patient.

**Thoracic Surgery**

Thoracic surgery differs significantly from abdominal surgery for several reasons but foremost is the pleural space and ventilation. The thoracic wall, diaphragm, and respiratory muscles are responsible for creating pressure changes in an awake or anesthetized animal that cause passive movement of air in and out of the lungs. When we open the pleural space to environmental pressure by thoracotomy no passive movement of air in and out of the lung will occur, therefore the anesthetic management must include assisted ventilation.

**Indications** There are many indications for thoracotomy in small animal practice. Nonpulmonary reasons to enter the thoracic cavity include cardiovascular anomalies such as PDA, and PRAA, esophageal disease or foreign bodies, constrictive pericarditis, chylothorax and for repair of epiphrenic diverticulae and/or hiatal hernias. Examples of pulmonary disease that necessitate exploratory thoracotomy include lung lobe torsion, lung neoplasia, lung abscessation, constrictive pleuritis and for diagnostic purposes to define etiology or locate lesions causing hemothorax or spontaneous pneumothorax. The choice of approach to the thoracic cavity is based on the location of thoracic disease within the chest and the degree of exploration necessary to achieve the surgical objective.

**Instrumentation for Thoracic Surgery**

Thoracic structures are intolerant to trauma. Tissues such as lung and mediastinum tear easily. Special retractors (Finochiettos) are used to spread the ribs during lateral thoracotomy. Many noncrushing clamps are used in the thorax to handle and manipulate tissues. Examples include Satinsky, Potts, DeBakey and Bulldog vascular clamps, Lung grasping forceps, and DeBakey thumb forceps. In general, the grasping portion of these instruments have a broader surface area so the pressure felt by the tissue is spread over a larger area, and the “teeth” or ridges are not sharp. Retraction of mediastinum, pleura and vessels using vascular tapes, stay sutures or specialized instrumentation is technically difficult and requires specialized training to be proficient.
Which Approach?

One of the most important decisions that must be made prior to thoracic surgery is which approach is most appropriate to accomplish the goal of the surgery. Traumatic injuries to the thoracic cage, such as rib fractures or open chest wounds are generally easy decisions, but other nontraumatic conditions are sometimes more difficult. The reason this is important, is that in contrast to abdominal surgery where surgeons can get to almost every structure via a ventral midline approach, structures in the thorax are not as movable or retractable because of the partitioning mediastinum and a few small vessels, and because the thorax is more rigid and more difficult to retract. The thorax is also laterally compressed in small animals.

This shape limits what can be exposed by a lateral approach to the thorax to those structures ipsilateral to the approach. Median sternotomy allows exposure of the entire thorax but because of the position of the carina and hilar regions of the lungs, it is difficult to remove a lung lobe via this approach. The thoracic approach to the esophagus varies with the region of involvement. For example, a bone lodged in the esophagus at the heart base is not accessible via a left fifth intercostal incision (lateral thoracotomy), because the aorta, pulmonary arteries and carina are in the way. That region of the esophagus must be approached from the right side of the thorax. It cannot be approached by median sternotomy because the heart is in the way. The following are examples of preferred approaches for various surgical problems that occur in the thorax.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Side and Intercostral Space</th>
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<tbody>
<tr>
<td>Right cranial lobectomy</td>
<td>Right 4th ICS</td>
</tr>
<tr>
<td>Right middle or caudal lobectomy</td>
<td>Right 5th or 6th ICS</td>
</tr>
<tr>
<td>Left cranial lobectomy</td>
<td>Left 4th or 5th ICS</td>
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<tr>
<td></td>
<td>Left 5th or 6th ICS</td>
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<tr>
<td>Patent ductus arteriosus</td>
<td>Left 4th ICS</td>
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<tr>
<td>Persistent right aortic arch</td>
<td>Left 4th ICS</td>
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<tr>
<td>Esophagus at heart base</td>
<td>Right 4th to 6th ICS</td>
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<td>Esophagus (prediaphragm)</td>
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<tr>
<td>Thoracic duct ligation (Dog)</td>
<td>Right 9th or 10th ICS</td>
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<td>Thoracic duct ligation (Cat)</td>
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<tr>
<td>Subtotal pericardiectomy</td>
<td>MEDIAN STERNOTOMY</td>
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<tr>
<td>Thoracic exploration</td>
<td>MEDIAN STERNOTOMY</td>
</tr>
<tr>
<td>Pacemaker implantation</td>
<td>MEDIAN STERNOTOMY</td>
</tr>
<tr>
<td></td>
<td>Midline abdominal (transdiaphragmatic)</td>
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</table>
Intercostal approach

The correct interspace is easily identified by palpation of the 13th rib cranially or by palpation of the 1st rib caudally. A rough anatomic landmark for a 4th intercostal thoracotomy includes an incision which is done at the level of the 1st mammary gland. Alternatively the scalenus muscle can be used as a consistent landmark. It is located under the latissimus dorsi and one of its muscle bellies inserts on the 5th rib; thus, it is a very good marker for finding the 4th intercostal space.

For lateral thoracotomy incision we choose not to section the latissimus dorsi muscle. The surgeon can carefully undermine between the latissimus dorsi and underlying scalenus and serratus muscles thereby allowing adequate dorsal retraction with an army/navy retractor. Maintenance of the latissimus dorsi muscle offers three advantages: (1) the surgical closure is much more rapid; (2) there is less intraoperative bleeding and less postoperative pain when the muscle is not sectioned and (3) this broad, flat muscle helps to form a better seal after the ribs are approximated. When incising the intercostal muscles it is best to center the incision midway to the caudal 1/3 of the intercostal space to avoid the neurovascular bundle which runs immediately caudal to the cranial rib. Exposure to the thoracic cavity may be increased by rib resection or rib transection. These procedures can be done in instances when the standard intercostal approach does not provide adequate visualization necessary to complete the surgical procedure. However, these procedures carry with them inherent increased difficulty of reapproximating the ribs.

Closure of the lateral thoracotomy is achieved by approximating the ribs with 0 PDS for patients greater than 20 kg. In patients under 20 kg 2-0 PDS, can be used to reapproximate the ribs. In general, 5 to 6 encircling sutures are necessary for larger dogs whereas 4 to 5 encircling sutures are adequate for dogs under 10 kg. We choose to pass the encircling ligatures using mosquito hemostats and push the suture through the intercostal musculature rather than utilizing the needle passage technique in which there is a greater chance of lacerating the lung. Prior to closure of the lateral thoracotomy a thoracostomy tube should be placed within the entrance point being a minimum of two intercostal spaces caudal to the thoracotomy incision. Preplacement of the thoracostomy tube allows it to be positioned appropriately within the thoracic cavity. If pneumothorax is suspected as a postoperative complication dorsal placement of the tube is warranted. Conversely, if fluid collection in the hemithorax is anticipated a ventral placement is more ideal.

Inspiratory excursion of the ribs following thoracotomy is painful to the animal. In fact human patients undergoing lateral thoracotomy actually experience more pain than those undergoing median sternotomy. To lessen pain during respiration, improve movement and subsequently improve postoperative ventilation, local blocks of the intercostal nerves at the
rib heads are warranted. One-half milliliter of bupivacaine should be injected subpleurally at two intercostal spaces cranial and two intercostal spaces caudal to the incised space. The incised intercostal space is also injected. This intercostal nerve block has the advantage of giving postoperative analgesia for approximately 4 hours and avoids the central respiratory depression associated with a narcotic analgesic such as morphine.

Median Sternotomy

When the surgical lesion cannot be well localized from the preoperative radiographic work-up median sternotomy provides excellent bilateral visualization of the thoracic cavity. Median sternotomy offers the advantages of exploration of both sides of the chest for pericardial lesions, bilateral pulmonary lesions, and exposure of the cranial and caudal mediastinum. The incision also can be extended caudally to deal with cranial abdominal lesions. The main disadvantage of the technique is that it causes a fair amount of pain and that pulmonary lobectomy is often more difficult particularly in very deep chested dogs.

After incising the skin and subcutaneous tissues the fascia and underlying muscles are elevated from the sternum using a periosteal elevator. Hemorrhage is often moderate to heavy and is controlled with electrocoagulation. Division of the sternebrae is difficult because the bones are narrow and have a prominent ventral ridge. Sometimes the ridge can be scored with a number 10 scalpel blade to help guide a pneumatic oscillating bone saw. The oscillating saw is used to cut a groove deep enough so that the sternebrae can then be separated using an osteotome and mallet. If an oscillating saw is not available the entire procedure can be done using an osteotome and mallet taking care to stay on the median ventral ridge of each sternebrae. An alternative is to use a Lebsheke sternum splitting knife. I have found this instrument extremely useful and definitely the most rapid way to perform this procedure. After the entire sternum has been split it is packed off with moistened laparotomy sponges and a standard rib retractor is applied.

Closure of the sternum involves the use of monofilament stainless steel wire in dogs greater than 10 kg. In dogs less than 10 kg or cats heavy #1 monofilament polypropylene or nylon suture can be used. The sternebrae can be approximated using encircling cerclage wire or a figure-of-eight wire pattern which passes around the costal attachment to each rib. In general, the figure-of-eight sutures will align the sternebrae well whereas the encircling ligatures will compress and oppose the sternebrae better. Therefore we utilize a combination of three or four encircling wires and three or four figure-of-eight wires in our closures. Following wiring of the sternebrae the muscle bellies are reapprosed using 2-0 monofilament absorbable suture and subcutaneous tissues and skin are closed routinely.

Since the animals lie on their sternebrae a well-padded bandage is recommended after surgery to minimize direct trauma to the wound. Narcotic opiates are also used to relieve pain during the first 24 hours. Incisional complications such as swelling, discharge, infection, and wound dehiscence are more common because of the direct trauma to the wound. Also sternebral osteomyelitis and nonunion have been reported and are difficult postoperative problems to deal with. Most animals are reluctant to walk for 48 hours following surgery but begin to ambulate after this with less difficulty. Because of motion due to constant respiratory excursions and direct trauma the sternal wires will usually cycle and ultimately break. We have found that the encircling wires are less likely to break than the figure-of-eight wires. The broken wires do not generally cause clinical problems and do not require surgical removal unless they begin to migrate.

Pulmonary Lobectomy Techniques

Indications for pulmonary lobectomy include primary neoplasia, lung abscesses, traumatic injuries such as massive contusion with intrapulmonic hemorrhage and lung lobe torsion.
Lobectomy by definition is the removal of a lobe of a lung whereas pneumectomy is the removal of an entire lung. Lobectomy or pneumectomy can be performed either via a lateral thoracotomy or through a median sternotomy approach. Adjacent lung lobes are reflected and are packed out of the way with moistened laparotomy sponges. The hilar area is approached from the cranial dorsal position and the bronchus is located by palpation and dissection. The pulmonary artery is located dorsolateral to the bronchus. The vessel is isolated with curved right-angled forceps and triple ligated with 2-0 silk suture. The center ligature is usually a transfixation ligature. The vessel is then transected between the distal two ligatures. The lung lobe is retracted cranial dorsally and the pulmonary vein is isolated ventromedial to the bronchus. It is ligated and divided in similar fashion to the artery. The bronchus is then isolated and double clamped with vascular forceps. The bronchus is transected leaving a 3-4 mm stump and the lung is discarded. Interrupted horizontal mattress sutures of 3-0 PDS are preplaced across the stump of the bronchus and sequentially tied. The end of the stump is oversewn with a simple continuous suture of 4-0 PDS. The noncrushing clamp is removed and the bronchial stump is checked for leaks. Additional cruciate mattress sutures are utilized to close any leaks.

For rapid lobectomy we prefer the utilization of the TA30 autostapler equipment (United States Surgical Corp, Norwalk, CT 06856). The visceral pleura is reflected down to the hilus and the entire lung lobe can be rapidly removed using the 2.8 mm (white) vascular cartridge. This usually occludes the vessels adequately and any residual leaks from the bronchus can be hand sutured. The relatively large size of the autostapler usually precludes its use in animals smaller than 3 kg. In these toy dogs and cats I have successfully utilized large hemoclips for rapid and effective lung lobectomy. After careful dissection down to the lobar bronchus the pulmonary artery, vein and bronchus can be double clipped en mass with good surgical results. This technique is equally as fast as the utilization of the autostapling equipment. To perform a pneumonectomy the main stem bronchus is isolated and all lobar arteries and veins are collectively autostapled. In larger dogs two overlapping staple lines may be necessary. Up to 50% of the lung mass can be safely removed in the dog.

Peripheral lobectomy can also be attempted via hand suturing technique. An atraumatic vascular clamp or Satinsky forceps are used to clamp off the tissue to be resected. A continuous horizontal mattress suture of 4 or 5-0 swedged on nylon or prolene suture is then placed just beyond the clamp. The mass is resected, the clamps are removed in a simple continuous pattern is then used to oppose the free pleural edge. A thoracostomy tube must be placed after hand sewn partial pneumectomies as postoperative pneumothorax usually is present for 24-48 hours.

Partial lobectomy is indicated for peripheral lobar lesions such as pulmonary bullae or in certain instances of tumor metastasis where complete lobectomy is not advisable. We usually use the TA30 autostapler with the vascular cartridge to facilitate partial lobectomy. For peripheral lesions two cartridges can be fired forming a V beneath the lesion. Hand suturing can also be performed by first clamping below the lesion with a vascular clamp such as a pediatric Satinsky forcep and then applying overlapping handsewn horizontal mattress sutures of 40 or 50 PDS. The cut edges are then approximated with a simple continuous suture pattern. There is usually more air leakage with the handsewn partial lobectomy than with the autostapled technique but this usually resolves within 12-24 hours. At the conclusion of all lobectomy techniques a thoracostomy tube left in place and periodically aspirated at 2-4 hour intervals for the first 24 hours.

**Thoracostomostomy Tube Placement**

Once surgery with the thorax is complete, a chest drain (thoracostomy tube) is placed to allow evacuation of air and fluid from the pleural space so respiratory muscle can intermittently create subatmospheric intrathoracic pressure allowing the animal to breathe on.
its own. Chest drains are tunneled a short distance under the skin (two or three intercostal spaces), and then "punched" into the pleural space while guarding thoracic structures from the tip of the drain. The drain is generally directed to lay anterior and toward the ventral aspect of the thoracic cavity but this may vary depending on the nature of the thoracic disease. Usually only one chest drain is placed but one on each side may be used for thoracic diseases such as pyothorax.

Chest drains remain in place after surgery for 12 to 24 hours (sometimes longer) so that control of the pleural space is maintained should air, fluid, or hemorrhage accumulate. Occasionally, iatrogenic injury to the lung parenchyma may occur and be unrecognized prior to closing a thoracotomy, the chest drain will allow earlier recognition of such a problem. Prior to closure warmed sterile saline is place in the pleural space to check for air leakage during lung inflation. A Pleurivac system may be used to simultaneously evacuate air and fluid from the pleural space. This system and similar systems will quantitate fluid obtained from the pleural space but cannot quantitate air evacuated. Chest drains are removed when air no longer escapes into the pleural space and the production of fluid decreases.

Management of pain associated with thoracic surgery, in addition to making the patient more comfortable, is also important to ventilation. Parenteral administration of narcotics such as morphine is beneficial, and intercostal nerve blocks using bupivacaine are also helpful. Placement of local anesthetics into the pleural cavity has also been shown to be beneficial, but is not used as frequently because of concern for potentially locally blocking the phrenic nerves, and of an inability to keep the analgesic agent at the site of the incision. When median sternotomy is done, rigid stabilization of the sternal osteotomy is important to decrease pain that is associated with instability.

Thoracotomy incisions regardless of the site are protected by nonadherent padded bandages, and the animals must be restrained from the bandage and especially the chest drains. Tube clamps are often placed on chest drains in addition to the standard three-way stopcock to assure obstruction of the drain when not attached to a closed evacuation system.

**Additional Reading**