Pneumonectomy: four case studies and a comparative review

Pneumonectomy is the resection of all lung lobes in either the left or right lung field. The surgical technique and postoperative results of pneumonectomy for clinical disease have not been reported in companion animals. Pneumonectomy was performed in three dogs and one cat to treat pulmonary or pleural disease, and the postoperative outcome compared with the complications and results reported in the human literature. One dog died immediately postoperatively due to suspected respiratory insufficiency and the remaining three animals survived the perioperative period. Postoperative complications were reported in two animals. Cardiac complications occurred in the cat, with perioperative arrhythmias and progressive congestive heart failure. Gastrointestinal complications were diagnosed in one dog, with mediastinal shift and oesophageal dysfunction. Left- and right-sided pneumonectomy is feasible in companion animals, and the postoperative outcome and complications encountered in this series were similar to those reported in humans.

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Introduction

Pneumonectomy is the resection of all lung lobes in either the left or right lung field (Nelson 1993, Nelson and Monnet 2003). In the dog, the left lung consists of the cranial and caudal parts of the cranial lobe and the caudal lobe, and the right lung consists of the cranial, middle, caudal and accessory lobes. The left and right lungs account for 42 and 58 per cent of the lung volume, respectively (Hsia and others 1992a). Previously, right-sided pneumonectomy was not recommended in animals due to the likelihood of fatal pulmonary hypertension following resection of more than 50 per cent of lung volume (Nelson 1993). However, despite increased pulmonary vascular resistance after pneumonectomy, pulmonary arterial pressure remains within the normal reference range in experimental animal and clinical human studies (Hsia and others 1990a, Tronc and others 1999). Furthermore, numerous experimental studies have shown that normal dogs can tolerate pneumonectomy of either the left or right lung (Davies and others 1982, Murray and others 1986, Pompapathi and Jayadevappa 1988, Hsia and others 1990a,b, 1992a,b, 1993, 1994a,b,c, Carlin and others 1991, Takeda and others 1999).

In normal dogs, pneumonectomy results in compensatory changes in the contralateral lung and myocardium with resultant improvement in oxygenation. Initially, residual lung volume, vital capacity and maximal breathing capacity are decreased to approximately 50 per cent of preoperative levels. Residual lung volume increases significantly after three months and total lung capacity increases up to 37 per cent more than expected for a normal, single lung (Hsia and others 1992a, Tronc and others 1999). The three principal compensatory mechanisms responsible for these changes are recruitment of physiological reserves of existing diffusing capacity, remodelling of the existing alveolar-capillary network, and new or regenerative alveolar-capillary growth, especially in immature animals (Davies and others 1982, Carlin and others 1991, Hsia and others 1994a,c, Tronc and others 1999, Nelson and Monnet 2003). Left pneumonectomy or resection of less than 50 per cent of the lung volume results in compensation by existing mechanisms only, whereas regenerative growth occurs in addition to existing compensatory mechanisms when right pneumonectomy or resection of more than 50 per cent of lung volume is performed (Hsia and others 1994a).

Following pneumonectomy, increased pulmonary blood flow and distension in the remaining lung are responsible for inducing these compensatory mechanisms (Hsia and others 1994a, Wu and others 2000). As a result of these changes, compliance, vital capacity and perfusion are decreased in the remaining lung, while pulmonary vascular resistance increases resulting in right ventricular hypertrophy (Nelson and Monnet 2003).
In humans, a number of pneumonectomy techniques have been described, including standard and video-assisted thoracoscopic pneumonectomy (Rice 1999, Roviaro and others 1999). A technique similar to the standard procedure has been described for cats and dogs (Nelson and Monnet 2003). However, to the best of the authors’ knowledge, pneumonectomy has only been reported in one dog for the management of hypertrophic osteopathy (Madewell and others 1978). In humans, the risk of perioperative morbidity and mortality is relatively high and a knowledge of the types of complications and their management is important when performing pneumonectomy.

The aims of the present paper were first to describe the peri- and postoperative outcome of pneumonectomy in four animals with pleural or pulmonary disease, and secondly to review and compare the results and complications associated with pneumonectomy using these cases as examples.

**MATERIALS AND METHODS**

The medical records at Colorado State University Veterinary Teaching Hospital were reviewed for cats and dogs treated with pneumonectomy between January 1993 and June 2002. Inclusion criteria for cats and dogs in which pneumonectomy was performed were that complete medical records and adequate follow-up information were available. Animals were excluded if subtotal pneumonectomy was performed, defined as preservation of one or more lung lobes in either the left or right lung fields.

The records of each animal were reviewed and information recorded on signalment, presenting signs, physical examination findings, diagnosis, anaesthetic complications and surgical findings, adjunctive treatment and postoperative outcome. Surgical findings included approach (median sternotomy or intercostal thoracotomy), side of pneumonectomy (left or right), surgical technique (suture ligation or stapler), complications and volume of intravenous fluids administered from the time of anaesthetic induction to extubation.

Outcome was evaluated in two different time frames: short-term (0 to five days) and long-term (>five days). Information for short-term outcome was recorded from the medical records and included analgesic technique, duration of thoracostomy tube placement, and type and duration of supplemental oxygenation. Long-term outcome was evaluated by telephone interview with the owner and referring veterinarian and assessment of postoperative thoracic radiographs, if available. Long-term outcome was broadly classified into the following categories: respiratory, cardiac, gastrointestinal and disease-related. Survival time was defined as the period from surgery to death.

**RESULTS**

**Case 1**

A six-year-old, female spayed Brittany spaniel was referred for treatment of a pyothorax when 2520 ml of purulent material was aspirated from thoracostomy tubes inserted into the left and right hemithoraces. On physical examination, the dog was recumbent and weak with dyspnoea, decreased lung sounds over the left hemithorax and pyrexia (rectal temperature 39.7°C). Haematological abnormalities included mild anaemia (packed cell volume [PCV] 35 per cent, reference range [RR] 40 to 55 per cent) with a moderate neutrophilia (19·8×10³/µl, RR 3·0 to 11·5×10³/µl) and left-shift (band neutrophils 8·9×10³/µl, RR 0 to 0·3×10³/µl). Serum biochemical abnormalities included hypoalbuminaemia (13 g/litre, RR 27 to 45 g/litre), hypoproteinaemia (38 g/litre, RR 54 to 74 g/litre), hypoglycaemia (5·1 mmol/litre, RR 6·5 to 22·0 mmol/litre), and elevated alkaline phosphatase (353 iu/litre, RR 18 to 141 iu/litre), aspartate aminotransferase (143 iu/litre, RR 16 to 40 iu/litre), y-glutamyl-transferase (8 iu/litre, RR 0 to 6 iu/litre) and total bilirubin (6 µmol/litre, RR 0 to 4 µmol/litre).

Thoracic radiographs revealed a pneumomediastinum and moderate to severe pneumothorax with a large amount of pleural effusion in the ventral pleural space and an alveolar pattern in the cranial and middle ventral lung lobes. Cytological analysis of the pleural fluid was consistent with a septic inflammatory process with a white cell count of 139×10³/µl, consisting primarily of degenerate neutrophils and numerous intracellular and extracellular rods, bipolar rods and cocci. Microbiological analysis of the pleural fluid revealed a heavy growth of *Bacteroides* species, but fungal organisms were not isolated.

Conservative management, with drainage and lavage of the thoracic cavity and systemic antibiotics, was not attempted in this dog due to the rapid deterioration and severity of the presenting signs. The dog was anaesthetised within three hours of presentation for an exploratory median sternotomy. Intravenous ampicillin (22 mg/kg, Bristol-Myers Squibb) was administered at induction of general anaesthesia and every two hours intraoperatively. Analgesia included a continuous rate infusion (CRI) of fentanyl (6 µg/kg/hour, Abbott Laboratories) and a single epidural injection of preservative-free morphine (Duramorph; Elkins-Sinn). A median sternotomy was performed and the left lung appeared normal. The entire right lung and adjacent pericardium were necrotic and abscessated (Fig 1).

In consecutive order, the right middle, caudal, accessory and cranial lobes were resected with double ligation of their respective pulmonary artery and vein, and the bronchus was collapsed with interrupted horizontal mattress sutures, transected and oversewn with a simple continuous suture pattern. The type of suture material was not recorded. Subphrenic pericardiectomy was also performed due to involvement of the pericardium in the disease process.

Physiological abnormalities in cardio-respiratory function were not noted...
following resection of the middle, caudal and accessory lung lobes. However, oxygen saturation decreased from 91 per cent to 75 per cent and end-tidal carbon dioxide decreased from 22 to 17 mmHg following resection of the right cranial lobe. Mean arterial pressure decreased from 70 to 90 mmHg to 35 to 60 mmHg approximately 10 minutes after desaturation. Hypotension was treated with two boluses of intravenous fluids (Normosol R; Abbott Laboratories) and a CRI of dobutamine (Bedford Laboratories), which was sequentially increased from 2 to 6 to 10 µg/kg/minute over a two-hour period.

By the end of the procedure, oxygen saturation had increased to 98 per cent, end-tidal carbon dioxide to 28 mmHg and mean arterial pressure was 55 mmHg. The dog was transported from surgery to the critical care unit. Extubation was attempted; however, respiratory and cardiac arrest ensued which was unresponsive to cardiopulmonary resuscitation. Oxygen saturation and blood pressure measurements were not recorded during this period. The total volume of perioperative intravenous fluids was 1100 ml (24.4 ml/kg/hour).

Case 2

A 13-year-old, female spayed, domestic shorthaired cat presented with a four-week history of ataxia and vomiting. On physical examination, the cat was underweight with a grade III/VI continuous systolic heart murmur, tachycardia, tachypnoea and increased lung sounds over the left hemithorax. Haematology and serum biochemistry were performed, with a marked neutrophilia (126·9 × 10³/µl, RR 2 to 12 × 10³/µl) being the only noted abnormality. Thoracic radiographs revealed a well-defined soft tissue mass, measuring 4 × 5 cm, in the left caudal lung lobe.

The cat was anaesthetised for exploratory thoracotomy. A single dose of intravenous cefoxitin (22 mg/kg, ESI Lederle) was administered at induction of general anaesthesia. Analgesia was provided with intermittent boluses of intravenous fentanyl and an intraoperative intercostal nerve block using lidocaine (Vedco) and bupivacaine (Abbott Laboratories). A left-sided lateral thoracotomy was performed at the sixth intercostal space. The left cranial and caudal lung lobes were resected en bloc with a 30 mm vascular thoracoabdominal stapler (Auto Suture TA Premium 30; United States Surgical Corporation) as the mass in the left caudal lung lobe appeared to infiltrate into the base of the left cranial lobes. The stump of vascular and bronchial tissue was oversewn with 3-0 polypropylene (Surgilene; Davis and Geck) in a simple continuous suture pattern. Incisional biopsies of the sternal and hilar lymph nodes were submitted with the pulmonary mass for histopathological evaluation. A 10 French gauge thoracostomy tube (Argyle; Tyco Healthcare Corporation) was inserted and the lateral thoracotomy wound closed routinely.

Perioperative complications included cardiac arrhythmia and hypotension. Both arrhythmia and hypotension were detected following induction of general anaesthesia and prior to surgical intervention. The arrhythmia was not classified but treated with two intravenous boluses and then a CRI of lidocaine at 50 µg/kg/minute. A CRI of dobutamine at 1 µg/kg/minute was started when systolic blood pressure decreased to 50 mmHg. An initial response to dobutamine was observed and persisted for 40 minutes. Systolic blood pressure decreased from 160 to 60 mmHg and, as a result, dobutamine was replaced with phenylephrine (American Regent Laboratories) at 1 µg/kg/minute, which maintained systolic blood pressure above 120 mmHg. Oxygen saturation was maintained between 95 to 99 per cent throughout the procedure and the total volume of perioperative intravenous fluids was 125 ml (35 ml/kg/hour).

The cat recovered uneventfully. A CRI of fentanyl was administered for analgesic effects. Supplemental oxygen was not required. The thoracostomy tube was removed after 21 hours.

The cat was diagnosed with a pulmonary squamous cell carcinoma and metastasis to the hilar lymph nodes. Piroxicam (Feldene; TEVA Pharmaceuticals) was administered orally, at 0.3 mg/kg every second day, for possible antineoplastic effects. The cat died 89 days postoperatively due to progressive heart failure with the development of weakness, exercise intolerance and a left atrial thrombus. There was no evidence of respiratory difficulties, local tumour recurrence or metastasis during this period.

Case 3

A three-year-old, male German shepherd dog presented with a chronic history of coughing and weight loss. The dog was underweight but no other abnormalities were detected on physical examination, haematology, serum biochemistry or urinalysis. Thoracic radiographs revealed atelectasis of the left caudal lung lobe, hyperinflation of the right lung lobes and a mediastinal shift towards the left side resulting in left lateral and dorsal displacement of the heart. Complete closure of the left mainstem bronchus and absence of left-sided bronchi were identified on bronchoscopic examination of the respiratory tract. The dog was anaesthetised for...
exploratory thoracotomy. Cephazolin (22 mg/kg, West-Ward Pharmaceuticals) was administered at induction of general anesthesia and every two hours during surgery. Analgesia was provided with a CRI of fentanyl at 5 µg/kg/hour and an intraoperative intercostal nerve block using lidocaine and bupivacaine. A left-sided lateral thoracotomy was performed at the sixth intercostal space. The left lung lobes were atelectic while the right lung lobes appeared grossly normal. Pulmonary arteries and veins to the cranial and caudal parts of the left cranial lung lobe and left caudal lung lobe were ligated with 1 silk (Sherwood; Davis and Geck). The left mainstem bronchus was collapsed with interrupted horizontal mattress sutures of 3-0 polybutester (Novafil; Davis and Geck), transected and oversewn with the same suture material in a simple, continuous suture pattern. A thoracostomy tube was inserted and the intercostal incision closed routinely.

Intraoperative complications were not reported. Oxygen saturation was maintained between 93 and 97 per cent throughout the procedure with a partial pressure of oxygen (PaO₂) of 308 mmHg during resection of the left lung. The total volume of perioperative intravenous fluids was 1000 ml (13-2 ml/kg/hour).

The dog recovered uneventfully. A CRI of fentanyl was administered for analgesic effects. Supplemental oxygen was not required. The thoracostomy tube was removed after 14 hours.

Bronchiole agenesis and secondary severe diffuse atelectasis were diagnosed following histopathological evaluation of the left lung. The cause of bronchiole agenesis was not determined. The dog was alive 1005 days postoperatively with no clinical evidence of respiratory, cardiac or gastrointestinal problems.

Case 4

An 11-year-old, female spayed crossbreed dog presented with a two-week history of inappetence, coughing and wheezing. Lung sounds were increased over the left hemithorax and heart sounds were muffled on the right side. Haematological abnormalities included a mature neutrophilia (41·7×10³/µl), mild anaemia (PCV 40 per cent) and thrombocytosis (613×10³/µl, RR 200 to 500×10³/µl). Serum biochemical evaluation revealed hypoalbuminaemia (1·7 g/dl) and hypoproteinaemia (4·5 g/dl) with elevated alkaline phosphatase (183 iu/litre), aspartate aminotransferase (85 iu/litre) and creatine kinase (725 iu/litre, RR 50 to 275 iu/litre).

The dog was anaesthetised for computed tomography (CT) imaging and exploratory thoracotomy. Radiographs and CT scans of the thoracic cavity revealed a 7 cm mass in the mid-dorsal mediastinum causing compression of the right mainstem bronchus and ventral displacement of the heart (Fig 2). A sarcoma arising from the paravertebral musculature was suspected due to the degree of ventral compression; however, a primary lung tumour could not be excluded. Cephazolin (22 mg/kg) was administered at induction of general anaesthesia and every two hours during surgery. Analgesia was provided with a CRI of fentanyl at 20 µg/kg/hour and an intercostal nerve block of lidocaine and bupivacaine. A right-sided lateral thoracotomy was performed at the sixth intercostal space. A 10 cm mass was evident at the base of the right middle lung lobe which extended into the cranial and caudal lung lobes (Fig 3). The right lobar artery was double-ligated with 0 silk, immediately caudal to the point at which the lobar artery branches from the main pulmonary artery, and transected. The pulmonary veins were also ligated with 0 silk and transected. The right mainstem bronchus was collapsed with interrupted horizontal mattress sutures of 3-0 polypropylene, transected and oversewn with the same suture material in a simple continuous suture pattern. An incisional biopsy of the hilar lymph node was submitted with the right lung for histopathological evaluation. A thoracostomy tube was inserted and the intercostal incision closed routinely.

Perioperative complications included hypotension and acidosis. However, these problems were corrected during CT imaging and prior to surgical intervention.
PaO₂ remained relatively constant during 40 to 21 per cent. Oxygen saturation and cage being incrementally decreased from concentration of oxygen in the oxygen was used for 20 hours with the used for a further 34 hours. Supplemental tively and then intermittent suction was tube was used for four hours postopera-

Continuous suction of the thoracostomy

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The mass was diagnosed as an incompletely resected grade III bronchogenic adenocarcinoma. Carboplatin (Paraplatin; Bristol-Myers Squibb) was administered at 300 mg/m² every three weeks for four doses due to the increased risk of developing local recurrence with an incompletely resected lung tumour and metastasis with a grade III bronchogenic adenocarcinoma. Piroxicam (0-3 mg/kg) was also administered every second day for possible anti-neoplastic effects.

The major treatment-related postoperative complication was regurgitation which developed seven days postoperatively. Thoracic radiographs revealed a mediastinal shift with right-sided displacement of the oesophagus and heart. Gastro-oesophageal reflux was suspected secondar-

The physiological consequences and complications associated with pneumonectomy have been well described in normal experimental dogs but not in animals with pulmonary disease. In one respect, post-pneumonectomy adaptation is more likely to be successful in clinical rather than normal patients as the disease process may result in a compensatory increase in perfusion and ventilation in the normal lung due to decreased pulmonary function in the affected lung. However, in humans, pulmonary diseases are often not isolated and concomitant conditions, such as emphysema, chronic bronchitis and pulmonary fibrosis, can have a negative impact on the function of the remaining lung (Tronc and others 1999). Retrospective reviews in humans reveal a high rate of morbidity and mortality following pneumonectomy as a result of acute and chronic complications in respiratory, car-

FIG 4. Ventrodorsal thoracic radiograph of the dog in Figs 2 and 3 showing diffuse metastatic disease in the remaining lung. Note the shift of the mediastinum (thin arrows) and heart towards the right side and cranial advancement of the right diaphragmatic crus (thick arrow)
Table 1. Complications of pneumonectomy in humans

<table>
<thead>
<tr>
<th>Category</th>
<th>Acute complications</th>
<th>Chronic complications</th>
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<tbody>
<tr>
<td>Respiratory</td>
<td>Respiratory insufficiency, Pneumonia</td>
<td>Respiratory failure, Post-pneumonectomy syndrome</td>
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<td></td>
<td>Pulmonary oedema</td>
<td>Pneumonia</td>
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<td></td>
<td>Pulmonary thromboembolism</td>
<td>Pleural effusion</td>
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<td>Bronchopleural fistula/pyothorax</td>
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<td>Chylothorax</td>
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<td>Haemothorax</td>
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<td></td>
<td>Laryngeal paralyis</td>
<td>Congestive heart failure</td>
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<td></td>
<td>Supraventricular arrhythmia</td>
<td>Pericardial effusion</td>
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<td></td>
<td>Congestive heart failure</td>
<td>Pulmonary hypertension</td>
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<td></td>
<td>Myocardial ischaemia</td>
<td>Pulmonary oedema</td>
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<td></td>
<td>Cardiac herniation</td>
<td>Respiratory insufficiency</td>
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<td></td>
<td>Oesophageal dysmotility</td>
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<td>Oesophageal dilatation</td>
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<td>Oesophagopleural fistula</td>
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<tr>
<td>Cardiovascular</td>
<td>Local recurrence</td>
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<td></td>
<td>Metastasis</td>
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<tr>
<td>Gastrointestinal</td>
<td>Oesophageopleural fistula</td>
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<td>Metastasis</td>
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<td>Disease-related</td>
<td>Local recurrence</td>
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Cardiac and gastrointestinal function (Table 1). The complications encountered in the present series, despite the limitation of small case numbers, are representative of the most commonly reported complications in humans.

The mortality associated with pneumonectomy in humans is relatively high. Prior to 1940, the perioperative mortality rate for humans with pulmonary carcinoma treated with pneumonectomy exceeded 50 per cent (Klemperer and Ginsberg 1999). This mortality rate has decreased to below 10 per cent with better technique and, more importantly, increased awareness, monitoring and management of complications (Klemperer and Ginsberg 1999). In the present series, one dog died immediately postoperatively resulting in a perioperative mortality rate of 25 per cent. Risk factors for perioperative mortality in humans include advanced age (>70 years), mild to marked impairment of pulmonary function (as determined by spirometric analysis), concomitant disease (especially cardiac disease, diabetes mellitus and chronic obstructive pulmonary disease), right-sided pneumonectomy, any factor resulting in failure to extubate or reintubation, and excessive intraoperative fluid administration (Swartz and others 1997, Klemperer and Ginsberg 1999; Reed 1999).

An assessment of risk factors in companion animals was not possible in the present study due to the small sample size, although contributing factors to the one death may have included decreased preoperative pulmonary function, sepsis and severe concurrent systemic illness secondary to pyothorax. The significance of right-sided pneumonectomy and a high rate of intravenous fluid administration (24-4 ml/kg/hour) in this dog is unknown as both right-sided pneumonectomy (case 4) and higher rates of intraoperative fluids (case 2) were reported in the present series without complication. The relationship between disease chronicity and prognosis has not been investigated in humans but may be an important consideration in animals. Inadequate compensation of preoperative pulmonary function may have contributed to the one death in this series as this dog had an acute presentation and decreased levels of intraoperative oxygen saturation. In contrast, pulmonary compensation is more likely in the remaining three animals based on the chronic and insidious course of disease and intraoperative oxygen saturation levels greater than 96 per cent (Trione and others 1999).

The post-pneumonectomy morbidity rate is also high with major complications having a significant negative impact on quality of life in up to 36 per cent of humans (Klemperer and Ginsberg 1999). In humans, complications are defined as acute (0 to five days postoperatively) or chronic (>five days postoperatively). The most frequently reported complications involve the respiratory and cardiac systems, although gastrointestinal complications can also occur.

Acute respiratory complications in humans include respiratory insufficiency, pneumonia, pulmonary oedema, pulmonary thromboembolism, bronchopleural fistula and pyothorax, oesophagopleural fistula, haemothorax and chylothorax (Zwischenberger and others 1999). Respiratory insufficiency was suspected as the cause of death in case 1 as oxygen saturation suddenly decreased when the last remaining lung lobe was resected. However, other causes of compromised oxygenation, such as pulmonary thromboembolism or pulmonary hypertension, cannot be excluded in this dog.

Respiratory insufficiency is defined as the functional capacity of the residual lung being either temporarily insufficient or anatomically inadequate for gas exchange (Zwischenberger and others 1999). The risk of post-pneumonectomy respiratory insufficiency can be predicted with preoperative spirometric analysis of ventilatory function. However, these techniques are not readily available or interpretable in veterinary medicine (Ferguson 1999, Zwischenberger and others 1999). Contributory factors to respiratory insufficiency include any cause of inadequate ventilation, diffusion or perfusion, such as a mediastinal shift, pulmonary oedema, retained secretions and atelectasis in the remaining lung, and restriction of thoracic wall excursion due to postoperative pain (Zwischenberger and others 1999).

In the dog reported herein, an anatomical deficiency was suspected on the basis of acute oxygen desaturation. Blood gas analysis is suggestive of respiratory insufficiency with a decrease in the PaO2 and PaCO2, although PaCO2 may normalise or increase with subsequent hyperventilation (Zwischenberger and others 1999). In humans, the management of respiratory insufficiency is supportive with oxygen therapy, tracheostomy, and assisted or controlled ventilation (Zwischenberger and others 1999). Other respiratory complications are reported less commonly although, when they do occur, have a significant impact on morbidity and mortality. Pneumonia, pulmonary oedema, pulmonary thromboembolism, fistulae and various types of pleural effusion were not diagnosed in the present series (Zwischenberger and others 1999).

Cardiac complications include arrhythmia, myocardial infarction and congestive heart failure. The majority of these com-
plications are caused by exacerbation of pre-existing cardiac disease by the physiological sequelae of pneumonectomy, such as an increase in myocardial wall tension and contractile force and compensatory decrease in afterload due to the redistribution of capillary blood flow in the remaining lung (Davies and others 1982, Mehran and Deslauriers 1999, Reed 1999). Auscultation, electrocardiography and echocardiography are recommended prior to surgery to evaluate cardiac function and identify patients at risk of developing post-operative problems. A systolic heart murmur was detected preoperatively on auscultation in one cat in the present series and, although a definitive diagnosis of the cardiac abnormality was not obtained, complications included perioperative arrhythmias and progressive and ultimately terminal congestive heart failure.

Arrhythmias are the most common cardiac complication following pneumonectomy and can occur in up to 40 per cent of cases (Asamura 1999, Reed 1999). Most arrhythmias are supraventricular and include atrial fibrillation, atrial flutter, supraventricular tachycardia, premature atrial contractions and premature ventricular contractions (Asamura 1999). The causes are unknown although hypoxaemia, vagal irritation, atrial inflammation, pulmonary hypertension, right heart dysfunction and reduced pulmonary vascular reserve have been proposed (Asamura 1999, Reed 1999). Pre-existing cardiac disease with loss of pulmonary vascular reserve were the most likely causes of the unclassified arrhythmia in case 2. Management options include correction of underlying causes, electrical cardioversion and the use of digoxin and calcium-channel blockers (Asamura 1999, Reed 1999).

The mediastinal shift that occurs following pneumonectomy can result in displacement of the oesophagus towards the resected side. Oesophageal displacement also causes extramural compression by adjacent structures, dilation and decreased peristaltic contractions (Suen and others 1999). Postulated causes of oesophageal dysmotility include vagal nerve injury, local ischaemia, post-surgical scarring of the oesophagus and mediastinum, and a disturbance of the autonomic nervous system (Suen and others 1999). Regurgitation in case 4 was attributed to an oesophageal motility disorder secondary to a marked mediastinal shift. This dog was partially responsive to management with promotility and antisecretory drugs.

Conclusions

Pneumonectomy is a procedure which can be performed in cats and dogs, whether left or right-sided, although complications can occur and are comparable with those reported in humans. The surgical technique is similar to standard lung lobectomy. Respiratory, cardiac and gastrointestinal complications are relatively common and a knowledge of these complications and their management is important when performing pneumonectomy.

References

Temeling, dogs are 68 and 445-457.