Respiratory Surgery Online 'Mini Series'

Session 3: Lower Airway Surgical Conditions 2

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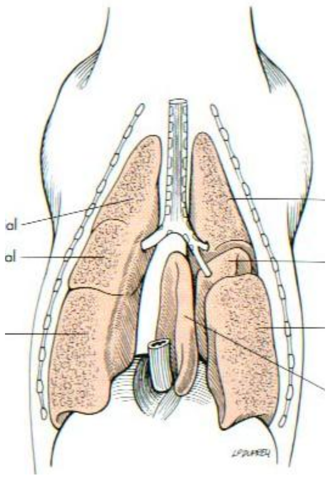

Anaesthesia for thoracic surgery

Successful thoracic surgery is as much about the anaesthetic management of the patient as it is about the surgical procedure performed (and the post-operative nursing care provided). The following notes provide just a small summary of some of the main considerations that `a surgeon should be aware of when considering performing a thoracic surgery.

Patient evaluation and stabilisation

It is imperative that during evaluation of a patient prior to thoracic surgery, the surgeon/anaesthetist must consider not only the thoracic procedure, but evaluate the patient as a whole. This includes:

- Patient factors: obesity, morphology (e.g. brachycephalics), temperament and age

- Pathology factors: problems associated with the surgical disease. The disease may involve other body systems – such as myasthenia and resultant megaoesophagus and risk of aspiration in the thymoma patient.

- Pre-existing/co-existing pathology: e.g. mild renal insufficiency/ Cushings disease etc.

- Procedure factors: particular risks will vary with procedure. Prior discussion with the surgeon will highlight areas of greatest concern and allow appropriate planning – for example ensuring adequate availability of blood products.

- Post-operative factors: anticipated problems in recovery such as mild hypoxaemia should be discussed and planned for.

History

Many chronically progressive conditions (e.g. pleural effusion or lung neoplasia) may present due to acute decompensation because clinical signs are not seen when the lesion is small. As a result, pathology may be extensive at presentation and animals may have very little functional reserve. These patients may tolerate the induction of anaesthesia itself very poorly, so it is vital that protocols are in place to ensure that all necessary equipment is conveniently to hand before anaesthesia is commenced. Exercise tolerance has been shown to be a specific risk factor in humans. Exercise tolerance gives some indication as to how well the patient will “tolerate” anaesthesia.

Physical examination

Pulmonary function and cardiovascular function should be assessed critically. Remember that cyanosis can not be perceived when haematocrit (Hct) is less than 0.15 l/l - most clinicians are not very good at detecting it anyway! Pulse oximetry can be used as an adjuvant technique. Physical examination can direct further testing, such as electrocardiography, echocardiography, radiography, computed tomography and bronchoscopy. Throughout the examination, and especially with cats, bear in mind that stress can be very deleterious. When preparing dyspnoeic cats for further interventions such as thoracocentesis, low dose opioid and an oxygen cage/incubator should be considered prior to any attempts to place an IV catheter. Consideration should be given to sympathetic positioning and the cat should be returned to the oxygen cage should deterioration occur at any point during handling.

Further testing

The results of advanced imaging and other studies should be evaluated to further characterise the disease process and likely implications for anaesthesia.

Haematology and biochemistry

A complete blood count and biochemical profile will help to identify co-existing disease. An elevated Hct provides supporting evidence for the presence of chronic hypoxia due to secondary polycythaemia. Reduced Hct can occur in trauma patients or those with a haemothorax resulting from neoplasia. Whilst a chronic fall in Hct to 0.15-0.2 l/l is often well tolerated, and tissue oxygen delivery is maintained by an increase in cardiac output, where the fall in Hct is acute and the cardiac output is fixed (e.g. aortic stenosis), a much higher Hct will be required. The necessity for pre-operative or intra-operative transfusion should be considered. Electrolyte abnormalities and hypoalbuminaemia may be present where large volumes of proteinaceous or sodium rich (e.g. chylothorax) fluids are present in the pleural space. Many animals that have not been eating adequately are hypokalaemic. Coagulation profiles should be evaluated in cases of non-traumatic haemothorax.

Arterial blood gas analysis

This provides quantitative evaluation of pulmonary function. The placement of an arterial catheter for direct blood pressure monitoring also allows for arterial blood gas sampling in recovery. Where arterial samples can not be obtained, a jugular venous sample can be used to assess acid/base status.

Pulmonary considerations

Drainage of pleural effusions prior to anaesthesia will help to optimise lung function in the period during induction of anaesthesia where hypoxaemia and hypotension are significant risks. Rapid drainage can precipitate severe hypotension because the removal of fluid causes vasculogenic shock. Clinically significant pneumothorax should also be drained prior to anaesthesia. Animals with severe pneumonia alongside a surgical disease should ideally not be anaesthetised until the pneumonia is controlled. Anaesthesia has significant deleterious effects on pulmonary function and recovering these cases can be extremely difficult.

Pulmonary contusions occur secondarily to blunt thoracic trauma. They occur due to ruptured small vessels which bleed into the interstitium and result in decreased gas exchange. They can result in pulmonary oedema that progresses to ARDS (Acute Respiratory Distress Syndrome) and severely compromises lung function. Ideally animals should be treated with cage rest and oxygen. Where anaesthesia cannot be avoided extreme care with ventilation must be employed. Low inspiratory pressures and avoidance of barotrauma are mandatory. Aggressive volume re-expansion should be avoided - this may promote further interstitial haemorrhage. The clinician should also be aware that many animals with pulmonary contusions also have myocardial damage secondary to trauma and arrhythmias.

In almost all cases, pre-oxygenation prior to anaesthesia (and prior to drainage where appropriate) may prevent hypoxaemia occurring during induction of anaesthesia. Care should be taken to avoid rapid changes in position and to keep the “functional lung” uppermost. Generally, dorsal recumbency is the most deleterious position for animals with pleural space disease, severe generalised parenchymal disease and pulmonary contusions. Ascites prevents adequate ventilation. Ascitic animals may also become profoundly hypotensive when placed in dorsal recumbency. Slow drainage of ascites may be appropriate and due care should be taken with positioning during anaesthesia.

Cardiovascular considerations

Where cardiovascular disease is present, either as a co-existing pathology or as part of the primary disease process in a patient due to undergo thoracic surgery, it may be prudent to delay the procedure to allow adequate time for optimal medical stabilisation. In trauma cases, electrocardiography is mandatory because arrhythmias due to myocardial contusions are common. Pericardial effusions causing any degree of right sided cardiac tamponade should be drained prior to surgery.

Anaesthetic technique

Ventilation

Where pulmonary or pleural disease or a large space occupying lesion is present, adequate pre-oxygenation may prevent hypoxaemia occurring during induction of anaesthesia. ‘Flow-by’ oxygenation is usually the most tolerable method of pre-oxygenating patients. Whichever technique is chosen, DO NOT cause stress to the patient by forcing it to accept an intervention – an alternative is to place the mask as the animal begins to lose consciousness, which is not as effective but still beneficial. Care should be taken with positioning during preparation for surgery. Nitrous oxide should be avoided because of its propensity to diffuse into any air filled spaces which may occur in the pleura. Nitrous oxide diffusion doubles the volume of a closed pneumothorax within 10 minutes.

Controlled ventilation from induction of anaesthesia may be necessary to maintain a normal end tidal CO_2 and SpO_2. Controlled ventilation must be established before entry into the thoracic cavity. Manual positive pressure ventilation (PPV) can be achieved by “squeezing” the reservoir bag but this is labour intensive. In practices doing more than the occasional thoracotomy, mechanical ventilation is necessary.The ventilator should be checked prior to anaesthesia and set up appropriately for the size of patient. Initial tidal volumes of around 10-12mL/kg are generally appropriate, except where pulmonary contusions are present when a lower tidal volume may be indicated. Peak pressures should be limited to around 20cm H_2O in the dog and 10cm H_2O in the cat. If higher pressures are required this suggests a reduction in airway compliance. This can be due to luminal obstruction e.g. material from an abscess. (suction should be available) Decreased compliance can occur with an iatrogenic pneumothorax, either through surgery or due to bulla rupture for example.

Positive end expiratory pressure (PEEP) is a useful addition to reduce the atelectasis that occurs when the “seal” between the chest wall the lung is broken. PEEP of about 5cm H_2O is generally appropriate. Occasionally, PPV can not be imposed without the animal “fighting” the ventilator. In these cases neuromuscular blockade (NMB) can be employed but adequate monitoring of depth of anaesthesia, PPV and NMB must be undertaken.

Where it is likely that ongoing air leakage will occur, removal of the volatile agent and provision of anaesthesia via a total intravenous technique may be required. Propofol at 0.1-0.3 mg/kg/minute plus an opioid such as fentanyl usually suffices. Where a neoplastic mass is present, some authors advocate the use of bronchial blockers or Fogarty catheters to block the affected lung lobe to prevent material from the lesion being expelled into the airways during surgery. Both techniques require dexterity with an endoscope and must be performed in theatre because the catheters can get dislodged when patients are moved. These techniques are not routinely used in our practice.

Surgical considerations

Good communication between surgeons and anaesthetist, before and during surgery is essential. When lung fields are packed off for oesophageal, mediastinal and cardiac surgery the area available for gas exchange is reduced as is PaO_2 and the difference between $PaCO_2$ and end tidal CO_2 increases (ventilation/perfusion mismatch). During sternal approaches, cardiac orientation may change, decreasing pre-load and thus cardiac output. Arrhythmias are common with this approach. If a large space occupying lesion is involved (e.g. thymoma), compression of multiple great vessels can occur and this is often exacerbated by surgery. In many surgeries, specific manipulations cause acute and profound hypotension due to reduction in venous return (preload) or ventricular function. The anaesthetist and surgeon must work together to “get the job done” but to try to minimise these deleterious effects.

Monitoring

The anaesthetist must ensure where possible that tissue oxygen delivery is maintained. Thus, cardiac output, haemoglobin content, tissue perfusion, ventilation and oxygenation must be adequate. In veterinary practice it is difficult to directly measure all of the above.

To assess ventilation and oxygenation a combination of pulse oximetry, capnography and arterial blood gas (ABG) analysis is ideal. The arterial blood gas analysis allows determination of "shunt fraction", $PaCO_2$ (which can be compared with end tidal CO_2) and early detection of changes in pulmonary function. The non-invasive monitors can be constantly referred to and allow early detection of de-saturation and ventilatory problems such as disconnection. Problems such as pulmonary thromboembolism or cardiovascular collapse will also be detected.

Ideally, an arterial catheter should be placed for arterial blood pressure monitoring and to allow ABG and Hct sampling. A central catheter will allow measurement of CVP and estimation of pre-load, which may aid in the management of hypotension. It also provides additional IV access should rapid infusions (eg blood) be required. Routine monitoring of airway gases, electrocardiography and temperature should be employed.

Analgesia

Provision of effective analgesia is imperative whenever thoracic surgery is contemplated. Sternotomy, especially in very deep chested dogs, is generally perceived as being much more painful than a lateral thoracotomy. Analgesia can be provided with parenteral opioids and NSAIDS (if these are not contra-indicated). Moderate pre-operative doses of opioids are unlikely to cause respiratory depression and may improve pulmonary function when severe pain is present. Short acting opioids such as fentanyl (5-15 mcg/kg/hour) can be infused during the procedure to enhance analgesia but the clinician should be cognisant of their potential adverse effects. Ketamine (5-10 mcg/kg/minute) and lidocaine (15-30 mcg/kg/minute) constant rate infusions (CRI) may provide additional analgesia. Local and regional anaesthetic techniques have much to offer. In addition, intercostal blocks with bupivacaine (1.5-2 mg/kg) performed at surgery (for lateral approaches) and infiltration of the sternum (for sternal approaches) is useful. In large thoracic wall surgeries, wound "soaker" catheters can be used to provide post operative analgesia without sedation (bupivacaine, 1.5-2mg/kg every 6-8 hours). Interpleural analgesia (bupivacaine every 6-8 hours) via chest drains is also very effective. Note that bupivacaine has a fairly low therapeutic index so guidelines suggest a maximal dose of 1.5-2mg/kg q 6-8 hours.The 0.5% solution (5mg/mL) can also be irritant - dilute with 0.9% NaCl at 100% of its initial volume for inter-pleural use and in wound catheters if reaction to injection occurs.

Urinary catheters in non-ambulatory patients can decrease post operative restlessness.

Post operative restlessness may require sedation/ tranquilisation. Whilst ACP is NOT an analgesic, it can be useful. Medetomidine CRI (1mcg/kg/hour) can allow a calm, 'stress-free' recovery.

Recovery

Animals undergoing thoracic procedures are at specific risk of post–operative hypoxaemia and the following should be considered:

- Supplemental oxygen (humidified) must be provided. Oxygen cages are useful but may limit nursing interaction. Nasal catheters or prongs can supply a FiO_2 in excess of 50% in small patients

- Monitoring pulmonary function via SpO2 and ideally arterial blood gas analysis allows adequate provision if additional O_2

- Normothermia should be assured. Hypothermia causes shivering and a massive increase in O_2 demand which may precipitate hypoxaemia

- Adequate analgesia improves ventilation. A “rough” recovery is likely to result in increases inO_2 demand resulting in hypoxaemia. Comfortable animals recover from surgery more quickly

- Chest drainage should be carried out to allow fluid/air drainage. Large volumes of fluid can lead to hypovolaemia so the measurement of INS and OUTS can be useful to aid fluid provision

- Cardiovascular monitoring for arrhythmias/hypotension etc should be undertaken particularly if the surgery involved extensive haemorrhage or resulted in significant arrhythmias

Lung Tumors

Incidence and Aetiology

Canine lung tumours are uncommon compared with the human counterpart, probably reflecting the influence of cigarette smoking. The clinical incidence in one study reported 4.17 cases per 100,000 dogs

Tumour Types

Carcinomas

- Papillary adenocarcinomas
- Bronchioloalveolar carcinomas
- Other carcinomas

Sarcomas

- Histiocytic sarcomas
- Osteosarcoma
- Chondrosarcoma
- Leiomyosarcoma
- Poorly differentiated sarcoma

Clinical Signs

Dogs with lung cancer are usually older (mean age = 9yrs), but it is important to remember that the disease can affect dogs of all ages (ranges 3 – 14 years) so clinical awareness is important.

The most notable feature for dogs with lung cancer is a non-productive cough. This may persist for several months in some cases. The dogs often remain bright, active and in good general health.

Other signs may develop as the tumour progresses. If the tumour has started to involve the bronchial airways, the cough may become productive or paroxysmal, and haemoptysis may also be observed. With very large tumours, or diffuse parenchymal disease (e.g. metastasis) exercise intolerance, orthopnoea and increased respiratory effort may be observed. Weight loss (cancer cachexia) or regurgitation may be observed rarely.

Diagnosis

Three-view thoracic radiographs (i.e. two lateral views, with a VD orthogonal view performed if any abnormal lesions are seen) should be performed as part of a general survey for the 'coughing dog'. Lung tumours appear as an area of increased soft tissue density within the lung parenchyma. They are usually discrete, with blurred edges. The films should be reviewed for any evidence of metastatic disease. Enlargements of peri-hilar lymph nodes may also be seen.

Bronchosopic examination (with BAL) may be considered in some patients, but is often of low diagnostic yield unless the cough is productive or haemoptysis is a clinical feature.

Case Management

Traditionally, no further imaging/investigation would be advised once a solitary parenchymal mass had been seen on radiograph as further diagnostic evaluations were regarded to be of limited use as the treatment (lung lobectomy) was going to be the same for all aetiologies. The considerations influencing this strategy was that transthoracic fine-needle aspirate biopsy has been shown to have a low diagnostic yield (except in round-cell malignancies) and has been associated with a high morbidity (some fatal) rate from pneumothorax, haemorrhage etc. The potential for tumour seeding into the thoracic cavity is also a significant concern.

Differential diagnoses for the radiographic lesion would include benign conditions (granuloma, abscess, torsion) and malignant conditions (cancer). The decision to proceed with invasive diagnostic tests will therefore be based on discussion with the owners, and whether they wished to proceed with surgery to remove the affected lobe on the basis of the differential diagnostic list alone. A definitive diagnosis was then achieved on excisional biopsy after surgery.

Recently, histological grade and the World Health Organization (WHO) tumour node metastasis (TNM) clinical stage designation has been shown to have prognostic significance in canine primary lung tumours. Median survival times in days for T1 tumours is 348 days (95% CI = 68 to 628), compared to 72 days for T2 tumours, and 23 days for T3 tumours. Tumour classified as stage T1N0M0 had superior survival times of 434 days (99 to 769) when compared to all other staging types (= 58 days (10 to 106))

World Health Organization classification scheme for canine primary lung tumours	
T1	Solitary tumour surrounded by lung or visceral pleura
T2	Multiple tumours of any size
T3	Tumour invading neighbouring tissues
N0	No evidence of lymph node involvement
N1	Neoplastic lymph node enlargement
M0	No evidence of metastases
M1	Metastases present

In addition to stage, histopathological type has been shown to be significantly associated with survival, with papillary adenocarcinomas exhibiting improved survival following excision compared with all other tumours combined, by both univariate and multivariate analysis. Lymph node status is also an important prognostic factor.

In light of these findings, the pre-operative strategy has shifted to focus on identifying ‘poor prognostic’ patients (i.e. those >T1N0M0 stage) as they are unlikely to benefit significantly from surgical invasion. Thoracotomy is a significant procedure which invariably entails postsurgical morbidity and a period of hospitalisation. Complications of thoracotomy include haemorrhage, pneumothorax, lung lobe torsion, pyothorax, thoracostomy infection, coagulopathy and subcutaneous emphysema. In one study, more marked morbidities were seen with T3 than with T1 tumours, and some patients died acutely in the peri-operative period due to failure of ligatures placed across tumour-infiltrated tissues. Chemotherapy may actually prove to offer more significant benefits than surgery in some cases as preliminary data using the drug vinorelbine have yielded favourable results in a small number of pulmonary adenocarcinomas.

Clinical stage determination is achieved with CT scan which allows for better assessment of lung parenchyma for small metastatic disease, lymph node status

Optimal Case Selection	
Clinical Signs:	• Clinically 'well' patient, with no evidence of haemoptysis or productive cough. • No systemic signs of disease (e.g. weight loss, exercise intolerance).
Radiographs:	• Solitary lung mass, located some distance from the hilus.
CT:	• Single, discrete lung mass, located away from the hilus (min 1cm) • No hilar lymphadenopathy seen

Surgery

Most lung tumours can be removed via an intercostal thoracotomy (interspace 4, 5 or 6 depending on the lobe being removed). Sometimes, a median sternotomy is required if the mass is particular large, but lobectomy via this route is technically more challenging.

Surgical considerations are as described elsewhere. The adjacent lobes can be packed off with saline-soaked swabs to allow better visualization of the hilus.

There is no doubt that stapling equipment has greatly enhanced the safety of lung lobectomy, and possibly made this procedure more accessible to the more general surgeon. However, these instruments have been designed for human patients and may not always be suited to some of our smaller patients. Failure of the staple line (with profound, life-threatening haemorrhage in the post-operative period) is a recognized complication. Wherever possible, I attempt to isolate the bronchial artery and vein and ligate these separately with suture material so I may be confident of my vessel security. The stapler is then used to perform the lobectomy. A vascular stapler should always be used as this provides three rows of staples - the double row stapler is acceptable for partial lobectomy.

The hilar area should be carefully palpated in all cases, and pinch biopsies taken from any enlarged lymph nodes. Positive lymph nodes are associated with reduced survival, so this knowledge is important.

Post-op considerations

As outlined in the section on thoracotomy management.

The patient should be monitored closely for signs of pneumothorax and haemorrhage. It should usually be possible to remove the chest drain on the morning after surgery, if not the previous morning.

Pain management is essential in all cases to ensure post-operative recovery is as smooth and uncomplicated as possible.

Chest Wall Tumours

Introduction

Tumours arising from the rib cage are typically of mesenchymal origin. Thus, osteosarcoma, chondrosarcoma and fibrosarcoma are more frequently described, usually arising from near the costochondral junction. Other solid tumours should always be considered, however, including mast cell tumours and other soft tissue sarcoma. Sometimes, inflammatory lesions (e.g. migrating foreign bodies) can develop which may mimic chest wall masses. Although these are very uncommon, they are an important differential as they carry a very different prognosis.

History and Clinical Signs

Patients with chest wall tumours are usually bright, in good general health with no outward signs of disease apart from a firm, immobile mass recently noted somewhere on the chest wall. Development of the mass can sometimes be quite sudden, so it is not unusual for the owner to ascribe some minor traumatic incident to its development. Pain can sometimes can be elicited upon palpation about the mass.

Other clinical signs are less common. If the mass has a large intrathoracic component causing cardiopulmonary compromise, then exercise intolerance, orthopaenia, syncopal collapse or arrhythmia may be observed.

Diagnosis

The palpable assessment of a mass usually leads to the clinical suspicion of neoplasia. Other differential to consider include tracking foreign bodies and intra-abdominal lesions (e.g. kebab stick perforation from the GI tract).

The presumptive diagnosis can usually be confirmed by fine needle aspiration biopsy and radiography. Radiographic changes of the bony chest wall may include deformation of the affected rib, which may include a mixed pattern of osteolysis and bony proliferation. A definite diagnosis is obtained by bone biopsy and histologic examination. The biopsy can be performed using a Jamshidi biopsy needle or Michele bone trephine.

For surgical planning, CT or MRI-scans can be invaluable to reveal the full extent of bony and surrounding soft tissue involvement by the tumour. The modalities serve as an essential tool to estimate the possibility for complete surgical excision, and to warn the surgeon of possible intra-thoracic adhesions that may be present.

Treatment

Management of chest wall tumour is best achieved by en-bloc surgical excision. Tumours of the chest wall should be excised with 2-3 cm margins. This leads to an en bloc resection of the thoracic wall and one or two normal ribs on either side of the tumour. Reconstruction of the thoracic wall is necessary after en bloc resection. Large portions of the chest wall can be removed as long as an airtight cover can be reconstructed. Careful surgical planning is essential to ensure complete tumour removal can be achieved, and air-tight closure of the chest defect can be accomplished.

Surgery

The skin and panniculus muscle are unlikely to be involved in the neoplastic process, so can be incised directly over the tumour. A small ellipse should be used around any biopsy/FNA tracts to ensure all tumour seeding tracts are removed. Information gained from the pre-op CT/MRI is then used to determine which underlying muscles may be infiltrated by the tumour (and therefore need to be removed), and which can be preserved for use in the closure methods. As much soft tissue needs to be preserved as possible, without compromising oncological margins. An entrance to the chest is obtained through a non-affected rib space and the tumour extension is checked by digital palpation or thoracoscopic techniques. The incision is lengthened to allow for a 2-3 cm margin proximal and distal to the gross tumour pseudocapsule.

An identical procedure is performed in the rib space on the opposite site of the tumour. The ribs are cut proximal and distal to the chest tumour using a rib cutter. The arteries and veins running on the caudal side of the rib are sutured with 3-0 absorbable suture material. After adhesions to the tumour are dissected, the tumour is removed and the thoracic cavity is thoroughly inspected for abnormalities.

Closure of the chest wall is performed after installing a closed suction chest tube. The optimal material to close the defect with is autogenous muscle – the latissimus dorsi can often be elevated from its origin and brought down to close a defect more ventrally located on the chest wall. Synthetic materials (e.g. mesh) still need to be covered with autogenous tissues to be securely airtight. Omentum may be useful in some cases. A thoracostomy tube is used to evacuated air and fluid from the chest for the immediate postoperative period. The subcutis and skin are closed routinely.

Post-operative considerations

With good anaesthestetic and surgical management, recovery following chest wall reconstruction is usually uncomplicated. Provision of adequate analgesia is essential following chest wall resection. The use of intrapleural and/or wound diffusion catheters for local anaesthesia with bupivicain, in combination with systemic opiates and NSAIDs should be utilized in every case.

Paradoxical movement of the chest wall may be observed during ventilation. Rarely is this associated with pulmonary compromise and usually settles as healing progresses and tissues become firmer. If respiratory difficulties are observed (and all other causes have been investigated and ruled out), then placing the animal on their side (with the 'flail' segment downwards) or placing a firm chest dressing should be all this is required to improve ventilation.

Complications such as pneumothorax, infection or pleural effusion may be seen if the autogenous tissues used in the chest reconstruction are compromised due to excessive tension. Salvage of this complication may prove very difficult if no further tissue is available for closure of the thoracic defect. Open wound management is not an option in this location.

Prognosis

The prognosis following resection of all chest wall tumours other than osteosarcoma is typically very good. For chondrosarcoma, tumour free survival of >1500 days are reported; for fibrosarcoma, local recurrence or metastasis may be a feature in some dogs resulting in a shorter overall survival. Osteosarcoma has the shortest survival following surgery with a median survival time (MST) of 290 days. Increased activity of total ALP was a predictive marker of a significantly decreased survival in dogs with osteosarcoma (210 days versus 675 days, $p = 0.0035$). Some authors have suggested that a bone biopsy should be routinely performed before surgical excision because surgery may not be advised if OS is diagnosed. However, histological diagnosis from biopsy specimens may sometimes be incorrect due to the small size of the specimen. Clients should always be warned that a definitive diagnosis may not be possible until the entire tumour sample has been assessed following surgery.

Thoracic Surgery: Diseases of the Oesophagus

1. Persistent right aortic arch

Extraluminal obstruction of the oesophagus most commonly occurs as a result of derangement in the embryonic development of the aortic arch. Anomalies in vascular ring development revolve around aortic arches 4 and 6. Normally, Arch 4 forms the subclavian artery and part of the aorta between the brachiocephalic trunk and descending aorta, whilst Arch 6 forms the ductus arteriosus. Problems arise when the development of vessels from each side of the aortic arch is transposed, resulting in compromise to other soft tissue structures about the heart (namely, the oesophagus).

Anomalies in aortic arch development are very rare in the cat, and are uncommon in the dog. Commonly affected breeds include the GSD, Irish Setter, Doberman, Great Dane, Weimeraner, and the Boston Terrier.

A persistent right aortic arch (with a left ligamentum arteriosum) is the most common anomaly, and occurs in about 95% of cases. Various other combinations of aortic arch development make up the remaining cases.

Clinical signs

The classic clinical sign of a persistent right aortic arch is regurgitation, with signs usually occurring from the time of weaning. The patient is also thin, and may be failing to thrive despite an apparently ravenous appetite. Distension of the cervical oesophagus (from the thoracic inlet) with air and food may be palpable in severe cases.

In most instances, the puppy is bright and healthy. However, if aspiration pneumonia has occurred, pyrexia, coughing and general malaise may be evident.

Diagnosis

A diagnosis is easily obtained with a combination of plain and contrast radiography. Positive diagnosis requires detection of a variable distension of the cervical/cranial thoracic oesophagus, with an obvious constriction at base of heart. A common error is to mistake congenital megaoesophagus for vascular ring anomaly. In the former condition, distension of the oesophagus is usually evident throughout the entire thorax.

Angiography may be useful for the diagnosis of atypical malformations of the aortic arch. The very low incidence of these more bizarre vascular derangements makes the routine use of angiography an unnecessary pre-operative intervention.

Surgical management

Vascular ring anomalies are a surgical disease. Early surgical correction is advisable to prevent progressive dilation of the cranial oesophagus, and to reduce the risk of development of aspiration pneumonia prior to correction. The extent of oesophageal dilation cranial to the ligamentous constriction can play have an important bearing on post-operative prognosis.

A left intercostal thoracotomy (at the 4th interspace) is performed. The lungs should be packed off with damp sterile sponges to provide good visualisation of the area of mediastinum cranial to the heart. Keep a continual eye on respiratory effort and oxygen saturations to ensure ventilation is not compromised by this action. Identify the major anatomical structures about the heart, noting the tight restrictive band crossing the oesophagus. Dissect through the pleura to isolate this band, before ligating with silk or prolene. The ligamentous band can then be divided. Once the band has been divided, it is essential to have the anaesthetist pass a Foley catheter or stomach tube into the oesophagus past the constricted region. Many small fibrous bands will continue to restrict the oesophagus, and these must be identified and resected. Failure to perform this important part if the surgery will lead to reduced post-operative success. The thoracotomy incision is then closed.

Thoracoscopy techniques for management of ligamentous arteriosus have now been described, to limit the need to invasive thoracic surgery. However, puppies are usually very tolerant of the small intercostal thoractomy and it is difficult to judge the potential benefits of a thoracoscopic approach.

Post-operative management

Effective analgesia is an essential element of all thoracic surgical procedures. With appropriate peri-operative care, juvenile patients usually make an excellent recovery from surgery.

Post-operative management for the persistent megaoesophagus is essential, with intensity of management dictated by the size of the oesophageal pouch. Elevated feeding, with food provided on a ‘little-and-often’ basis, will reduce the risk of aspiration pneumonia developing.

Prognosis

It is well recognised that prompt intervention is important, to limit the irreversible dilatation of the proximal oesophagus.

Original descriptions of the post-operative progress provided a poor long-term outlook, with only 9% of patients in one study considered to be normal following surgery. The more common result (67%) was relief of symptoms to within acceptable limits. However, an overall 40% ‘long-term’ mortality rate for the condition was also reported, with death usually through euthanasia because of severe aspiration pneumonia, or severe clinical signs.

A more recent report provides more optimism, with 92% of patients suffering no episodes of regurgitation after eating. The remainder (8%) had only occasional episodes of regurgitation. It is important to note that this study only evaluated dogs who had survived more than 6 months after surgery so there may be some earlier attrition not reflected in these ‘positive’ results. Nevertheless, this improvement may reflect improvements in surgical and peri-operative management, better case selection, and improved client communication on long-term care. Repeated oesophagograms in about 50% of patients in this study revealed that the megaoesophagus did not improve with time.

Patent Ductus Arteriosus

Closure of a Patent Ductus Arteriosus (PDA) is the most commonly performed corrective surgical procedure in dogs with congenital heart disease. Spontaneous functional closure of the ductus arteriosus should normally occur within hours of birth. In affected animals, the wall of the ductus is unable to constrict and thus remains patent, shunting blood from the descending aorta into the pulmonary artery.

Clinical Presentation

Signalment: PDA is seen more commonly in purebred, female dogs. Maltese, Pomeranians, Shetland sheepdogs, English springer spaniels, keeshonds, Bichon frise, miniature and toy poodles, and Yorkshire terriers are at increased risk. A genetic basis has been established in poodles.

History: Initially, animals with a patent ductus arteriosus will be clinically asymptomatic. With time, and depending on the size of the ductus, progressive cardiac failure will occur. More than 50% of affected animals may die within the first year of life. The most common complaint in symptomatic animals with left-to-right shunts are cough or shortness of breath (or both) due to pulmonary oedema. Animals with right-to-left or reverse PDA may be asymptomatic or have exercise intolerance and hindlimb collapse on exercise.

Physical Findings

The most prominent physical finding associated with PDA is a characteristic continuous (machinery) murmur heard best at the left heart base. The left apical cardiac beat is prominent on the chest wall (and displaced caudally) and a palpable cardiac "thrill" is often present. Femoral pulses are strong or hyperkinetic (water hammer pulse) due to a wide pulse pressure caused by diastolic runoff of blood through the ductus. Tall R waves (> 2.5 mV), wide P waves and deep Q waves on an ECG (lead II) are supportive of the diagnosis, but not always present. Atrial fibrillation or ventricular ectopy may be present in advanced cases.

The physical examination findings in animals with right-to-left or reverse PDA differ from those with left-to-right shunts. "Differential" cyanosis is typically present (i.e., cyanosis is most apparent in the caudal mucous membranes). Femoral pulses are normal. A systolic cardiac murmur, rather than a machinery murmur, is often present.

Radiography/Echocardiography

Thoracic radiographs show left atrial and ventricular enlargement, prominent pulmonary vessels, and a characteristic bulge of the descending aorta on the dorsoventral view. Echocardiography provides information that further confirms PDA and helps rule out concurrent cardiac defects. Echocardiographic findings that support a diagnosis of PDA include left heart enlargement, pulmonary artery dilation, increased aortic ejection velocity, and a characteristic reverse turbulent Doppler flow pattern in the pulmonary artery.

With right-to-left PDA, thoracic radiographs show evidence of biventricular enlargement and marked enlargement of the pulmonary artery segment. Pulmonary arteries may also appear tortuous.

Clinical Management

Medical management

Animals with pulmonary oedema should be given furosemide for 24 to 48 hours prior to surgery. If atrial fibrillation is present, the ventricular response rate should be controlled using digoxin (with or without -adrenergic blockers or calcium channel blockers) prior to surgery. If haemodynamically significant arrhythmias are present they must be controlled. Complete resolution of clinical signs of congestive heart failure may be difficult with medical management alone.

Shunt Closure

Closure of left-to-right ductus is recommended in affected animals, and is usually performed as soon after diagnosis as is possible. Patient size may influence this decision. The traditional method for PDA management is open ligation via left intercostal thoracotomy. Alternatives to surgical ligation of PDA have been investigated for many years. Options for clinical management of PDA are presented in this summary of three recent papers examining treatment options for PDA.

Surgical Management

Surgical management of PDA is achieved by open ligation of the patent vessel via a left intercostal thoracotomy. The most commonly reported problems associated with this method include death due to rupture of the ductus during dissection and residual ductal flow post-operatively due to incomplete ligation or recanalisation. In addition, the relatively high morbidity and cost associated with thoracotomy can result in owners declining such intervention in their pet. Reported operative and overall mortality rates for surgical PDA repair of between 2 – 8 % and 7 - 11% respectively have been reported.

Standard Surgical Technique

Perform a left 4th space intercostal thoracotomy. Identify the left vagus nerve as it courses over the ductus arteriosus and isolate it using sharp dissection at the level of the ductus. Place a suture around the nerve and gently retract it. Isolate the ductus arteriosus by bluntly dissecting around it without opening the pericardial sac. Pass a right-angle forceps behind the ductus, parallel to its transverse plane, to isolate the caudal aspect of the ductus. Then, dissect the cranial aspect of the ductus by angling the forceps cranially approximately 45 degrees. Complete dissection of the ductus by passing forceps from medial to the ductus in a caudal to cranial direction. Grasp the suture with right-angle forceps. Slowly pull the suture beneath the ductus. If the suture does not slide easily around the ductus, do not force it. Regrasp the suture and repeat the process, being careful not to include surrounding soft tissues in the forceps. Pass a second suture using the same manoeuvre. Alternatively, the suture may be passed as a double loop and the suture cut so that you have 2 strands. Slowly tighten the suture closest to the aorta first. Then, tighten the remaining suture. Ductal closure without division is safer than surgical division, but re-cannulation of the ductus may occur. Because ductal division requires added technical expertise, it should be undertaken only by experienced surgeons.

Discussion on Surgery

Van Israel N., Dukes-McEwan J., French A.T. Long-term follow-up of dogs with patent ductus arteriosus. Journal of Small Animal Practice, 2004. 44(11); 480-490

This was a very extensive paper and is deserving of close scrutiny, but will only be briefly reviewed here. This paper principally reviewed the echocardiographic features following PDA closure. However, the paper also attempted to compare different closure methods, and long term survival in dogs following closure and non-closure of a PDA. A variety of parameters were assessed, including survival times, physical, radiographic and ECG findings, and the results of detailed pre- and post-ligation echocardiography examinations.

Data from 80 dogs was reviewed in this paper. Of these, 29 had undergone a conventional surgical procedure to close the ductus (standard surgery = 22 dogs, Jackson technique = 7). There was no significant difference in the techniques, with similar rates of residual shunting, late closure and recanalisation occurring. Residual flow through the ductus was detected in 46% of animals, a rate much higher than previously described. This may be because residual flow was detected by echocardiography in this paper, rather than relying on auscultatory findings. The presence of residual flow did not appear to affect survival times. More importantly, this paper suggests that development of mitral regurgitation and mitral endocardiosis may be a significant compromising factor in the outcome of animals with PDA.

2. Thrombogenic coils

Sisson D. Use of a self-expanding occluding stent for nonsurgical closure of patent ductus arteriosus in dogs. J Am Vet Med Assoc. 2003;223(7):999-1005.

The introduction of thrombogenic coils and other similar devices in the 1990s provided a viable alternative to surgical intervention, and is now the preferred method of PDA repair in humans. There are now several papers in the veterinary literature demonstrating that a catheter-delivered occluding stent can be used successfully to close PDAs in dogs. Catheter delivered techniques are attractive in the management of PDA because they are minimally invasive, and associated with a reduced risk of ductus rupture during dissection. Technical problems with the coils include uncontrolled release, misplacement, embolisation and incomplete occlusion of the PDA. These problems occur particularly when the PDA is too large, or there is no focal narrowing of the ductus to allow lodgement of the coils. The specific design of the stent used in this recent study appears to offer considerable advantages over other transcatheter techniques.

This study evaluated the clinical application of a catheter-delivered, self-expanding mushroom-shaped device specifically designed for closure of patent ductus arteriosus (PDA). The device is manufactured in 6 sizes, and is filled with polyester patches designed to act as a thrombogenic sieve to obstruct blood flow. Vascular access was achieved via the femoral vein and artery. The occluding stent, attached to a delivery cable, was manoeuvred with fluoroscopic guidance though the right side of the heart into the ductus via a prepositioned introducer sheath. The stent was released once its correct position was confirmed with angiography.

There were 23 dogs in this study. Two morphological types of PDA were identified on the basis of angiography. In the majority of animals (20/23), the ductus resembled a funnel or cone. In the remaining dogs, the PDA resembled an elongated narrow tube. Angiography performed after stent deployment indicated PDA closure in 13 of 20 (65%) dogs. There were no operative deaths. There were two deployment failures, but both were attributable to operator error and inexperience. There were 2 postoperative deaths in dogs with heart failure; both deaths were thought to be unrelated to use of the occluding stent. Complete PDA closure, determined by Doppler colour-flow echocardiography, was evident in 17 of 19 dogs within 3 months and in 1 additional dog within 1 year of stent deployment, resulting in closure in 18 of 19 dogs completing the study protocol.

The mushroom-shaped device utilised in this study appears perfectly suited to conform to the ductal anatomy with minimal potential for dislodgment and embolisation. A variety of sizes are available, thus ensuring a perfect ‘fit’ can be accomplished for different morphological shapes of ductus and patient size.

3. Thoracoscopic Surgery

Borenstein N, Behr L, Chetboul V, et al. Minimally invasive patent ductus arteriosus occlusion in 5 dogs. Vet Surg. 2004;33(4):309-13.

Progressive development of skills in thoracoscopy will inevitably lead to attempts to utilise this technique for procedures for which there is an accepted ‘open’ surgical alternative. Although the use of thoracoscopy for PDA ligation may be considered innovative in veterinary surgery, thoracoscopic occlusion has been performed in human infants since 1991 and is associated with a success rate similar to open ligation but with a lower complication rate. Reported advantages of minimally-invasive surgery include reduced tissue trauma, minimal post-operative pain, shortened recovery period and improved cosmesis.

This study described the results of a technique for minimally invasive occlusion of patent ductus arteriosus (PDA) and outcome in 5 dogs. Three dogs had video-enhanced mini-thoracotomy PDA occlusion. Two other dogs had thoracoscopic PDA occlusion using a custom-designed thoracoscopy clip applicator. Soft tissues were dissected cranial and caudal to the ductus in the usual fashion, but no attempt was made to dissect about the medial aspect. Titanium ligating clips were used for PDA closure in all dogs.

Thoracoscopic PDA occlusion was successful in both dogs in which it was attempted. Complete PDA closure was achieved in 4 dogs. Three months after surgery, the largest dog had residual ductal flow that haemodynamically was insignificant. Although technically demanding, minimally invasive PDA occlusion appears to be a safe and reliable technique in dogs. The authors note that preoperative measurement of the diameter of the PDA is crucial to determine if complete closure with metal clips can be achieved. Dogs with a PDA >11-12 mm are not suitable candidates for this technique as the haemostatic clips are not large enough to completely occlude the ductus.

In this study, closure of the PDA was successfully achieved in 4 dogs, with minimal residual shunting occurring in another dog. Technical aspects of thoracosopic surgery result in compromises to established surgical principles. In this report, dissection of the shunt was limited to the cranial and caudal portions of the PDA, prior to placement of a haemostatic clip. Such an approach would perhaps be ‘frowned’ upon with conventional open surgery due to the potential for incomplete closure of the vessel.

Observation of the dissection was enhanced by intrathoracic illumination and by the magnified image on the television monitor. This is a notable advantage compared to the view often obtained during open ligation procedures in very small neonatal patients. Minimally invasive PDA occlusion should therefore be considered as a developing alternative to occlusion via conventional thoracotomy. However, the procedure requires considerable experience with thoracoscopic techniques.