Clinical Updates in Small Animal Practice

Session: Updates in Cardiac Surgery

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INTRODUCTION:

Although many trained surgeons are comfortable performing closed cardiac procedures such as ligation of a patent ductus arteriosus and sub-total pericardectomy, only a few veterinary surgeons the world over perform open heart surgery regularly and perhaps even fewer can boast reliable long-term results for the therapy they perform. The reasons for this include: the prevalence of surgically correctable cardiac disease in veterinary patients, the apparent success of non-surgical treatment (eg. Balloon dilation for pulmonic stenosis), the risk surgical treatment poses to the patient, the techniques currently available and the cost of such treatments. For these reasons, cardiac surgery in animals has fallen massively behind when compared to the repertoire of procedures currently offered to human patients with heart disease. Ironically, the techniques used in human patients to facilitate open heart surgery today are largely the same as the techniques developed by pioneers such as Gibbon, Lillehei, Taussig and others, as a result of experiments with dogs and cats. More recently, open heart surgery programmes have been or are being developed at different centres throughout the world, increasing the availability, safety and success of open heart surgical therapies in the dog.

TECHNIQUES

Traditionally, open heart surgery was performed under total venous inflow occlusion (TVIO), placing time constraints on the duration of procedures. The trade-off for increasing the “safe” occlusion time for a patient was a reduction in the likelihood of successfully reviving the patient at the end of the procedure.

Venous inflow occlusion

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Time (mins)</th>
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<tbody>
<tr>
<td>Normothermic</td>
<td>3 – 5 mins * (8 mins – Hunt)</td>
</tr>
<tr>
<td>Mild hypothermia (30 C)</td>
<td>9 mins</td>
</tr>
<tr>
<td>Moderate hypothermia (25 C)</td>
<td>15 mins</td>
</tr>
<tr>
<td>Deep hypothermia (20 C)</td>
<td>45 mins</td>
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This time constraint often meant that procedures were designed to be fast rather than accurate and that some procedures needed to be aborted before the surgical goals were achieved. These techniques did, however, allow resection of fibromuscular atrial bands (as in cor triatriatum dexter and double chambered right ventricle in cats), resection of pulmonic valve leaflets or placement of a pulmonary outflow patch to treat pulmonic stenosis, and the resection of right ventricular outflow tract tumours. Studies demonstrating the long-term results of, for example, pulmonary outflow patching under TVIO, do not exist. Although short-term survival for patients undergoing such procedures is high at some institutions, the evidence, via personal communication, is that long-term results are either poor or at least very inconsistent.

The ability to open the heart, without the time constraint that TVIO creates, would allow the surgeon to perform a more accurate operation for even the relatively simple congenital cardiac diseases such as pulmonic stenosis. This should result in better long-term results. Theoretically, such techniques would open the way not only for treatment of congenital heart diseases but also offer some hope for all the dogs that develop progressive acquired valvular disease. Longer duration open heart surgery can be achieved in two ways:
Cardiopulmonary bypass

Heart-lung machine - unlimited time

Equipment:

In addition to standard surgical and anaesthetic equipment, in order to perform open heart surgery, an artificial pump (roller head pump) and an artificial lung (oxygenator) are required.

Personnel:

A dedicated co-ordinated team effort is required to perform operations under cardiopulmonary bypass. This team includes: two surgeons, two scrub-nurses, one anaesthetist, and an anaesthesia nurse or technician, a perfusionist to run the heart-lung machine and critical care specialists to perform the post-operative care for these animals. In addition, cardiologists need to be prepared to offer surgical therapy to their patients and need to co-ordinate the medical heart therapy prior to and following surgical therapy.
Re-inventing the wheel.

Unfortunately, over the last few years, those involved in such programmes have to a large extent had to re-learn the lessons learned by early workers in the human field of cardiac surgery many years ago. The author of this presentation has been involved in an open heart surgery programme over the last 12 years and has concluded, as other workers have, that:

1. All members of the team (cardiologists, surgeons, anaesthetist, perfusionist, critical care clinicians) have to be dedicated to the programme, understand their roles, and be co-ordinated by a single leader.
2. Size matters: the insult associated with being on a heart lung machine using current protocols is magnified in small dogs this means that small dogs often die of bypass related complications using protocols that are well tolerated by larger (>15kg) dogs.
3. At the start of a programme, attempt relatively simple operations in dogs that have not exhausted their myocardial reserve, preferably animals with congenital disease.
4. Dogs with end-stage heart disease are not good candidates for surgical therapy performed by an inexperienced team.
5. Because of problems associated with long-term patient anticoagulation, valve replacement is fraught with long-term problems associated with thrombus formation and so this is not a good option for small animals.
6. This is an expensive, high risk endeavour that will be a drain on hospital resources, in order to survive within a hospital, it must be successful, not only in terms of acute patient survival but also in terms of long term survival and improved quality of life.

The future:

As centres around the world gain experience and expertise in the field of open heart surgery, the repertoire of procedures will be extended to include congenital and acquired valve defects, along with other congenital heart disease. In addition, as skill levels increase, it will become possible for workers in this field to offer therapies to dogs of all sizes, along with cats and perhaps even horses.
OPEN RESECTION OF PULMONIC STENOSIS AND DOUBLE CHAMBER RIGHT VENTRICLE

Introduction

Congenital stenosis of the pulmonary outflow tract is, along with patent ductus arteriosus and subaortic stenosis, one of the three most common congenital cardiac conditions seen in the dog. It is rare in the cat. Pulmonic stenosis (PS) is characterized as being subvalvular, valvular or supravalvular, according to the anatomical location of the constriction. In the most common form of PS (valvular), valve pathology varies from fusion of otherwise normal valve leaflets within a normal valve annulus, to fibrotic deformed valve leaflets in a pathologically narrowed valve annulus. Secondary cardiac changes such as right ventricular hypertrophy can add a dynamic component to the stenosis that may influence treatment options and choice. In addition, concurrent anomalies of the coronary artery exist in some breeds, making treatment even more problematic.

Commonly, the severity of pulmonic stenosis is graded as mild, moderate or severe, based on the pressure gradient estimated, by calculation, from the velocity of blood flow across the stenosis, derived by Doppler ultrasound interrogation. Such ultrasound examinations are typically performed in the conscious animal. Interestingly, historically, pressure gradients to classify the severity of a lesion were taken from pressure traces derived from catheter “pull-out” procedures that were performed in anaesthetized animals. However, the severity of the pressure gradient, the presence of clinical signs and the degree of secondary cardiac changes (right ventricular hypertrophy) are all taken into consideration when determining a treatment plan for an affected animal. Generally, animals affected clinically or that have “severe” disease on the basis of their pressure gradient, are considered as candidates for intervention.

Treatment options include procedures directed at the valve alone and procedures that have been designed to treat the valvular deformity, valve annulus narrowing and sub-valvular muscular hypertrophy simultaneously. No single treatment option is endorsed by a report of a carefully controlled clinical trial, with long-term outcome, in “significant” numbers of animals. Treatments that carry the least risk to the patient like balloon valvuloplasty (BV) have, therefore, gained popularity despite the lack of evidence documenting long-term efficacy in small animals, largely because of the well-documented effect of similar techniques in human patients. The “higher risk” surgical procedures have been reserved for dogs that have failed non-surgical treatments or dogs that are not considered “good” candidates for non-surgical treatment.

TREATMENT OPTIONS

Valve alone:

1. **Balloon valvuloplasty:** Often the first-choice for clinicians treating valvular PS in a breed that doesn’t suffer from aberrant coronary artery anatomy, (even if subvalvular infundibular muscular hypertrophy exists) where the pulmonic valve annulus is a normal size.

2. **Closed valvulotomy:** Using a mechanical valve dilator. Largely superseded by BV.

3. **Open valvectomy via pulmonary arteriotomy:** Performed under total venous inflow occlusion (TVIO). Used in dogs/cats when valvular disease alone is present and in patients that have failed BV or in patients where BV was not possible or considered inappropriate.

Valve, valve annulus and muscular hypertrophy:

1. **Closed patch grafting.** Six dogs reported in the literature.

2. **Modified open patch grafting**
   - **Orton** – *partial ventriculostomy under TVIO* Four dogs reported.
   - **Hunt** – “quick sew”*under TVIO* Eight dogs reported in the literature.
   - **Sackman** – *incised patch under TVIO*. Book chapter.

3. **Open patch grafting (Cardiopulmonary bypass)** None reported in literature. Success described by several workers. Perhaps gives the best opportunity to examine the valve leaflets and excise hypertrophied muscle. Most accurate placement of a “patch”. Not appropriate for small patients!!
4. Conduits. Only failed conduits reported in clinical cases in the literature. Success has been described by some workers.

For many patients with severe or symptomatic PS balloon valvuloplasty represents the safest first line of treatment even if infundibular muscular hypertrophy exists. For patients with predominantly valvular disease (i.e. normal valve annulus), in which BV is not possible or fails, the best view of the RVOT is achieved under CPB. Although this approach is associated with the highest short-term risk to the patient it probably offers the best chance at long-term palliation or improvement.

ATRIOVENTRICULAR VALVE REPLACEMENT

Pathoanatomy:

The mitral and tricuspid valve can suffer from both congenital and aquired (endocardiosis) deformity that creates predominantly valvular incompetence and occasionally stenosis. Replacement of such valves in people, is commonly performed and typically is done before secondary myocardial changes are advanced.

Valve replacement in dogs:

Experience with replacement valves in dogs is in its infancy. Mechanical valves have been placed in the mitral position in dogs but although dramatic results were obtained in the short-term, difficulty in maintaining life-long anti-coagulation resulted in devastating failure of the valve in many patients. Tissue valves (valves made from bovine pericardium or porcine valves) obviate the need for life-long anticoagulation in people and should be similar in the dog. Early results of tricuspid valve replacement using both bovine pericardial and porcine aortic valves, suggest that inability to manage anticoagulation even in the short-term can prove devastating in the long term for dogs undergoing valve replacement.

SURGICAL MANAGEMENT OF TETRALOGY OF FALLOT

Pathoanatomy

The primary pathoanatomy seen in dogs with Tetralogy of Fallot (ventricular septal defect, pulmonic stenosis and overriding aorta) can all be explained by embryological developmental defects of the endocardial cushions comprising the conotruncal septum.

Pathophysiology

Right to left shunting of blood results in underperfusion of the lungs resulting in systemic hypoxia and cyanosis. Compensatory polycythemia may be seen. The contribution of infundibular muscle to the right ventricular outflow tract obstruction can create both a dynamic and progressive component to this disease, accounting for worsening of signs with exercise and progression of disease despite fixed valvular and septal abnormalities.

Therapeutic options

Medical/conservative: Some mildly affected animals not require any treatment and will enjoy a good lifestyle, others will require medical therapy (beta-blockers) to give an acceptable quality of life. It has been suggested that approximately 25% of affected animals will not be controlled by conservative/medical means (Eyster and others 1976).

Surgical: Surgical treatments fall into two main categories: primary repair and palliative procedures. Primary repair of tetralogy of Fallot has been described several times in the veterinary literature (Herrtage and others 1983, Lew and others 1989) this requires cardiopulmonary bypass, advanced surgical expertise and currently carries a high mortality rate. Palliative surgical procedures: These were used extensively in human medicine prior to the advent of cardiopulmonary bypass and primary repair. Currently, some are used in infants as a “bridge” to primary repair, in severely affected individuals.
1. **Potts anastomosis.** (Side to side anastomosis of the aorta to the left main pulmonary artery)
2. **Blalock anastomosis.** (Anastomosis of the left subcalvian artery to the left main pulmonary artery)
3. **Modified Blalock-Taussig anastomosis.** The development of synthetic materials such as polytetrafluorethylene (PTFE) (Gore-Tex) that are relatively non-thrombogenic and can be created in tube form has allowed surgeons to modify existing techniques.
4. **Others:** Microvasular anastomosis of the left internal thoracic artery to the pulmonary artery has been described in a cat that had a failed “Fontan” procedure (anastomosis of the right atrium to the pulmonary artery)

**OTHER CONDITIONS:**

Once cardiopulmonary bypass techniques are mastered, the ability to perform open heart repairs for several conditions becomes possible. Such conditions include:

- Atrial and ventricular septal defects
- Valve dysplasia – stenosis or incompetence
  - Mitral
  - Tricuspid
- Excisional biopsy of intracardiac tumours.