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Introduction to Cardiac Pacing

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Cardiac pacing refers to the artificial electrical activation of the heart by a temporary or permanent pacemaker device. The pacemaker is used to stimulate depolarization in the atrium and/or ventricle or to regulate the electrical activity in the heart. Pacing represents one of the most sophisticated subspecialty of cardiology and demonstrates the interface between medicine and engineering. Basic cardiac pacing with human pacemakers has been applied to dogs for over five decades. It is also feasible in cats, although far more challenging. Pacing can be a life-saving procedure and markedly prolong life while preventing symptoms and enhancing quality of life in dogs and cats.

**INDICATIONS FOR PACING DOGS & CATS**

Pacemakers were developed to treat bradyarrhythmias and have been further refined to overdrive tachyarrhythmias, restore cardiac rhythm through the recognition of ventricular fibrillation and appropriate shocking of the heart, and resynchronize a failing heart. While each of these have been performed in dogs, the focus of this lecture is basic pacing for bradycardias. Cardioversion/defibrillator devices have been implanted in dogs, but are prone to programming problems and not advised at this time. Cardiac resynchronization is expensive and without clear clinical indications in our veterinary patients.

Pacing can be temporary or permanent. Temporary pacing can occur transvenously, across the esophagus, or transcutaneously. Permanent pacing can involve transvenous delivery of pacing electrodes or epicardial implantation. New “leadless” pacemaker electrodes are under clinical trial in humans. The main indications for pacing in dogs in cats are:

- Symptomatic bradycardia caused by
  - Sinus node dysfunction (sick sinus syndrome)
  - Persistent atrial standstill (atrial muscular dystrophy)
  - Atrioventricular block (AVB) – typically high grade second degree or complete (third degree) AVB
- Drug overdose is another potential indication if bradycardia cannot be overcome medically with atropine or a catecholamine.
- Pacing can be considered after successful cardiopulmonary resuscitation

Cats present a special situation because they can have periods of severe ventricular asystole alternating between normal sinus rhythm. Additionally, most older cats with complete AV block have a “fast” escape rhythm, usually in the range of 120/minute making pacing less valuable in this species unless there are documented bouts of asystole-syncope. Some examples of bradyarrhythmias are shown below.

**Dog: Complete AV block**

![Canine ECG](image-url)
It should also be stressed that prior to permanent pacemaker implantation, the patient should be carefully evaluated for concurrent cardiac disease and noncardiac disorders, especially malignancies because these can affect the prognosis and the practicality of the procedure. Dogs with silent atrium have a poorer prognosis if the ventricle becomes involved in the fibrotic process.

**TEMPORARY PACEMAKERS**

Most temporary pacemaker applications involve either: 1) transcutaneous devices applied during general anesthesia or after cardiopulmonary resuscitation; or 2) transvenous pacing prior to permanent pacing or prophylactically in a dog with conduction disease that is undergoing general anesthesia. Transesophageal pacing is practical if the problem is sinus node dysfunction (bradycardia/arrest) and it can be done relatively easily under anesthesia or heavy sedation. It is stressed that except for transvenous pacing, all other forms of temporary cardiac stimulation (transcutaneous and transesophageal) cause pain that can range from mild to moderate (for transesophageal) to moderate to severe (for transcutaneous). It is emphasized that transcutaneous pacing in an awake dog is likely to be inhumane. This can be readily understood by comparing the output needed for most transvenous pacing systems compared to transcutaneous system. One can usually capture the canine heart with 2 milliams (mA) transvenously; whereas, it often takes more than 100 mA to capture the same heart with transcutaneous electrodes.

**Transcutaneous pacing** requires a transcutaneous pacing system. These are usually integrated with a cardioversion/defibrillator. Human electrodes are applied to each side of the shaved thorax at the levels of the ventricles. After attaching electrode connectors the large pads are wrapped in Vetwrap or a similar bandage material. Once anesthesia is administered the current output is gradually increased from 5 mA to higher than 100 mA until the heart is captured. This is best monitored by both ECG and pulse because an artifact of
pacing will appear on the screen (look for a distinct QRS and especially a related T-wave). A palpable pulse and Doppler signal is additional reassurance of capture. The disadvantage of this approach is the relatively violent muscular contraction that can attend each pulse stimulation. Accordingly this is a “safety-valve” approach at best. We typically set the system to a low escape rate (35 to 40/min) in VVI mode (see below).

Transvenous temporary pacing first requires vascular access. Typically, the jugular vein or (in larger dogs) the lateral saphenous or femoral vein is used. A local anesthetic block and modified Seldinger approach can be used to place an introducer sheath. If relatively long-term pacing is contemplated (for example in the ICU), a shield (“septishield”®) can be placed over the lead to allow for repositioning of the lead without contaminating the system. Pacing kits also include large over the needle catheter introducers matched for the pacing lead. Temporary leads come in a variety of French sizes and shapes. A 4 or 5 French temporary pacemaker lead is used in cats and small dogs and a 5 to 7 Fr pacing lead is used in bigger dogs. Flow directed (balloon) catheters are available and can be very useful. Fluoroscopy is best for guiding the placement of these leads, although they can be blindly advanced with relatively high success in dogs. Once the proximal ends are attached to an appropriate connector and a temporary pacemaker or pacemaker analyzer, pacing can commence. The leads are bipolar and the current exits one electrode, stimulates the heart, and re-enters the catheter through the other electrode. Unipolar pacing can also be done if a clip is used to attach the pacing system to the skin. The patient should be well grounded with an ECG system. The electrodes are usually advanced into the right ventricle for patients with AVB. For sinus node disease atrial pacing can be used, although lead movement can change pacing thresholds and too much current is more likely to stimulate the phrenic nerve and lead to “thumps”. Remember that many simple temporary pacemakers do not have a “sensitivity” control and this can only be modified by adjusting the pacing mode between VVI (demand) and VOO. The temporary system should be placed initially in full “demand” mode (VVI) and current increased until the heart is captured (usually 2 to 5 mA are sufficient but higher current might be needed). Importantly, the operator might need to turn the control gradually towards “asynchronous” mode (VOO) if T-waves are sensed and inhibit the temporary pacing system.

Transesophageal pacing is best done with special large electrode catheters (see papers by Sanders and colleagues). This is only useful if the problem is sinoatrial in origin. It is an unreliable method for pacing dogs with complete AV block. Pacing current is gradually increased until atrial pacing spikes are observed and atrial capture ensues. Gentle advancement or withdrawal of the catheter can improve pacing and allow for lower current outputs. The same temporary pacer used for transvenous pacing is generally used for transesophageal pacing.

PERMANENT PACING

Permanent transvenous pacing is performed most often in dog. As will be demonstrated in the lecture, the system is placed under general anesthesia with a permanent transvenous lead – typically bipolar – placed within the RV and the pulse generator buried under superficial muscle in the cervical region. In our practice we attached transcutaneous electrodes; anesthetize the patient; steriley prepare the skin; quickly cut down to expose the jugular vein; place safety ties around the vein; perform a venotomy; place the permanent lead under fluoroscopic guidance; attach sterile temporary pacing electrodes to capture the heart; secure the lead in place by sewing the sleeve to deep tissues; make a pacer pocket...
dorsal to the between the shoulder and base of the ear; attach the two via tunnel; routinely close the wounds.

In most cases, a ventricular single lead pacemaker is programmed into a rate responsive mode (VVIR) are sufficient. In young large dogs we usually place an atrial lead and ventricular lead and program the generator to DDD or VDD mode (so the ventricle can respond to native sinus activity via the pacemaker). Placement of two leads requires more advanced programming to prevent pacemaker induced tachycardias and to foster appropriate sensing of native rhythms.

Epicardial pacing is challenging. This is done mainly in cats to avoid a complication of chylothorax, although the author has successfully performed transvenous pacing in 5 cats without complication. This procedure requires a skilled surgeon and is done using an abdominal incision and trans-diaphragmatic approach in most cases. I only recommend this approach for cats, tiny dogs or in cases where an abdominal incision might already be planned, as in a dog with a benign splenic mass and AV block. The risk of fibrosis and exit block is very high as a long term complication even with skilled placement. Lead dislodgement is also possible.

Basic pacemaker programming involves consideration of the following codes: Letter code (5 – letters; 3 or 4 typically used)

- 1st - Chamber that is paced (A, V, D, where D means “both”)
- 2nd - Chamber sensed for electrical activity
- 3rd - Response mode (I, T, D, O) I = inhibited; T = triggered; D = dual; O = none
- 4th - Rate-response or sensor triggered
- 5th - Tachycardia treatment
  (Pace, Shock, Dual, O)

For example, in a VVIR (“demand”/rate responsive) implant (canine):

- Mode = VVIR
- Rate = 60 to 150 pulses/minute
- Amplitude = 2.5 to 5.0 V
- Pulse width = 0.4 to 0.5 msec
- Sensitivity = 2.5 mV to 5 mV
- Refractory period 220 to 260 msec

Special programming devices are needed for this and assistance of pacemaker company representatives is often needed.

**FOLLOW UP**

Immediate complications include lead dislodgement, especially in larger active dogs. For that reason a post-operative x-ray is taken and repeated in about 10 days or earlier if there are any signs of pacer malfunction. Infection rate is very low in experienced hands. Prophylactic antibiotics are usually given but are not required. Programming and troubleshooting of pacing or sensing issues requires a more advanced knowledge of this technology. For example, T-wave sensing is common and can usually be overcome with reprogramming. Long term success is very good at experienced centers. Clients are taught to take the resting pulse and some will use an iPhone app to record and send EKGs to us.