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Artificial Cardiac Pacemakers for Use in Small Animals

Since the first case report in the late 1960s, implanted artificial cardiac pacemakers have become the treatment of choice for patients with clinical signs of bradyarrhythmias due to structural heart disease. In most cases, artificial cardiac pacing is accomplished by placing a hermetically sealed pulse generator in a subcutaneous pocket in the neck or lateral thorax just caudal to the scapula.

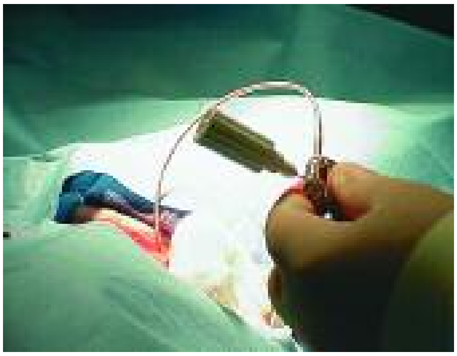
Transvenous Implantation

This pulse generator contains a lithium iodide battery and circuitry that generates electrical impulses that are delivered to the endocardium of the right ventricle via a transvenous lead wire. The transvenous lead wire can also propagate spontaneous myocardial depolarizations to the pulse generator so that the electrical activity of the ventricle can be sensed and monitored. This setup, along with sophisticated pacemaker technology, allows the pulse generator to pace the heart once a low heart rate threshold has been reached, or to "watch" the heart rhythm. The results are prevention of bradycardia, and battery conservation and safety when pacing is unnecessary.

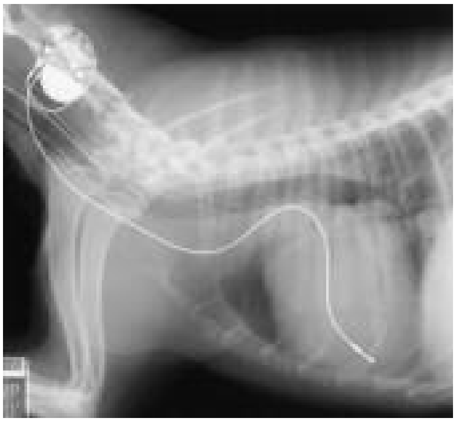
Abdominal Implantation

Transvenous pacemaker implantation using an endocardial lead may not be applicable in smaller mammals (such as cats, small dogs, and ferrets). In this scenario, the pulse generator is implanted in the abdominal cavity and the pacing lead is attached to the epicardium via a transdiaphragmatic approach.

Pulse generator placed in subcutaneous pocket



Attachment of the pulse generator to the pacing lead



Lateral (above) and ventrodorsal (right) thoracic radiographs demonstrating transvenous pacing system in place

About the Pacemaker

The pacemakers implanted in veterinary patients are not harvested from human cadavers or donors but are often unused units that have exceeded the Food and Drug Administration–mandated shelf-life (pacemaker units cannot be resterilized for use in humans). Several modalities of pacing are described by a specific pace-

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AV = atrioventricular

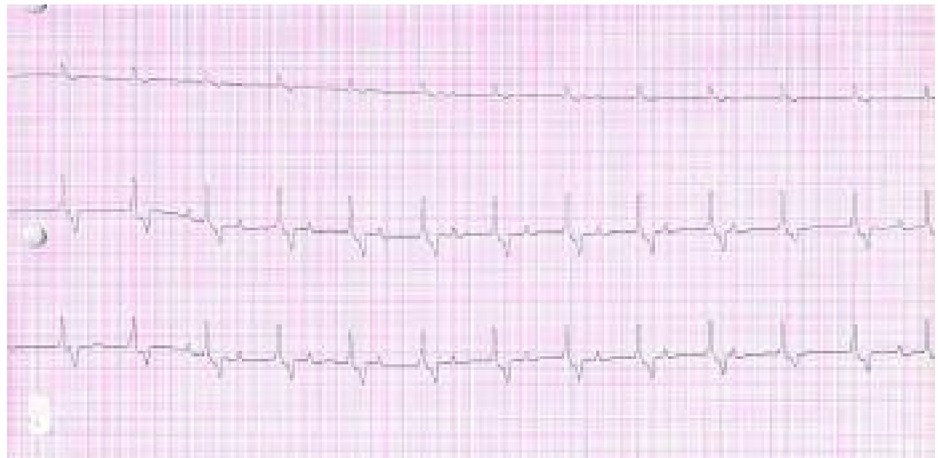
maker nomenclature that reflects the chambers being paced, the chambers being sensed, the response to sensing, and programmability or rate modulation used. In most veterinary cases, a VVIR (V = ventricular sensed, V = ventricular paced, I = inhibited mode, R = rate-adaptive programming) modality is used. In the minority of cases, other modalities that involve pacing or sensing of the right atrium and ventricle are used. The rate-adaptive function allows the pacemaker to increase the pacing rate through sensors that monitor physiologic processes, such as activity.

Although VVIR is the most commonly used pacing modality in veterinary medicine, it does not provide the most beneficial hemodynamic results when compared with "physiologic" dual-chamber pacing. With VVIR, the atrial contraction is not synchronized with the ventricular contraction. Furthermore, the location of right ventricular activation produces dyssynchrony between the left and right ventricles.

With dual-chamber pacing, the atrial and ventricular contractions can be synchronized to provide optimal loading of the ventricles before ventricular ejection. However, application of dual-chamber pacing (pacing of the atrium and ventricle or biventricular pacing) can be difficult or impossible in smaller patients.

In veterinary medicine, artificial cardiac pacemakers are most often implanted for treating bradyarrhythmias, such as advanced AV nodal block, sick sinus syndrome, and atrial standstill secondary to cardiomyopathy. In humans, another implantable device (implantable cardioverter-defibrillator [ICD]) is commonly used to prevent sudden death associated with tachyarrhythmias. Although ICDs have been implanted in veterinary patients (eg, a boxer dog with arrhythmogenic right ventricular cardiomyopathy), this device differs from that typically used to treat bradyarrhythmias. In addition to preventing sudden death in humans, cardiac pacing is a useful therapy for some patients with severe hypertrophic or dilated cardiomyopathy.

AV = atrioventricular

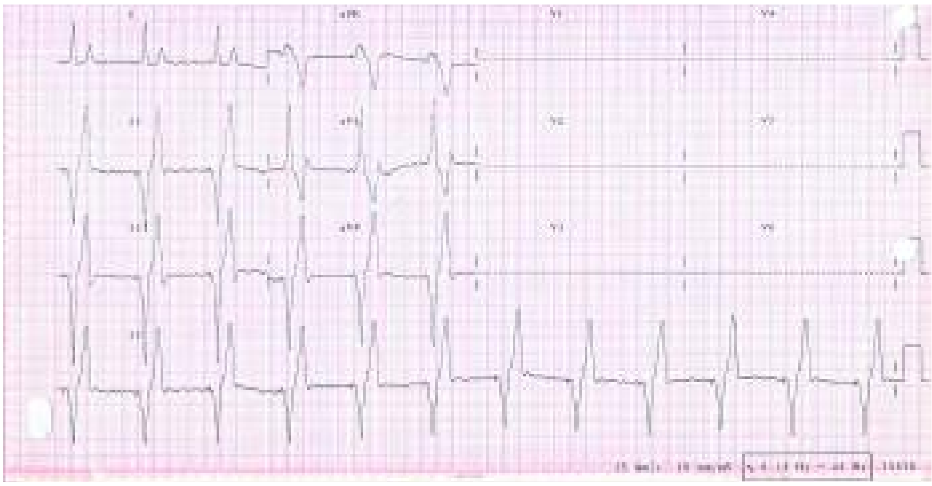


Electrocardiogram demonstrating advanced AV block in a dog

Indications

Implanted artificial cardiac pacemakers are the therapy of choice for patients with clinical signs of bradycardias. In general, this therapy is reserved for patients with clinical signs associated with the bradycardia. Typically, heart rates that are consistently less than 40 beats/min or heart rhythms that frequently result in ventricular asystole lasting longer than 4 to 5 seconds can be associated with clinical signs such as syncope, weakness, and lethargy. Decreased exercise capacity can result from an inability to increase the heart rate in response to increased sympathetic tone associated with exercise. It should be noted that many animals have subtle clinical signs that are recognized only after pacing has been performed. The most common bradyarrhythmias that cause clinical signs are advanced AV block, sick sinus syndrome, and atrial standstill.

- **Advanced AV block:** This arrhythmia results when supraventricular impulses from the sinus node are intermittently or completely prevented from propagating through the AV node, resulting in AV dissociation. The degree of this AV dissociation and the integrity of the ventricular subsidiary pacemakers (escape or rescue beats) determine the severity of the bradycardia and the likelihood of clinical signs. In advanced second-degree AV block and complete AV block, multiple sinus impulses are blocked and the ventricular heart rate depends on the ability of the heart to generate a junctional or ventricular escape rhythm (usually at heart rates between 30 and 60 beats/min). The slower the ventricular escape rhythm, the more likely clinical signs will be present. AV block is most commonly associated with degeneration or fibrosis of the AV node, although myocarditis, neoplasia, cardiomyopathy, and chemotherapeutic agents (doxorubicin) also have been implicated. In a recent study, the most common breeds presenting with advanced AV block were Labrador retriever, mixed-breed, and German shepherd dogs.
- **Sick sinus syndrome:** This arrhythmia most commonly occurs in middle-aged to older female miniature Schnauzer dogs and older dachshund, cocker spaniel, and West Highland white terrier dogs. The syndrome is characterized by supraventricular arrhythmias resulting in periods of sinus arrest and, in some cases, alternating periods of sinus arrest and paroxysmal supraventricular tachycardia. In most patients with this condition, periods of sinus arrest and ventricular asystole lasting longer than 5 to 8 seconds results in syncope.
- **Atrial standstill:** This arrhythmia is most commonly reported in English springer spaniel dogs and Old English sheepdogs, although it occurs in other breeds. It results



Electrocardiogram with pacemaker rhythm

from a progressive myocardial disease that results in destruction of the sinoatrial node and conduction system. Patients die of chronic bradycardia compounded by progressive myocardial dysfunction and heart failure.

Advantages

Transvenous artificial pacemaker implantation is considered to be associated with a high initial success rate without fatal complications during the first 48 hours and relatively low complication rates overall. Pacemaker implantation is highly effective for resolution of bradyarrhythmia, and the long-term prognosis is thought to be most affected by the presence of concurrent valvular or myocardial disease or systemic disease, such as neoplasia or renal failure. The procedure is associated with a high client satisfaction rate, is minimally invasive, and involves state-of-the-art human technologies for veterinary patients. A recent study by Schrope and Kelch demonstrated that pacemaker implantation was associated with significantly longer survival. Another study by Johnson et al showed that transvenous pacemaker implantation reduced or eliminated clinical signs in more than 90% of dogs with advanced AV block or sick sinus syndrome. This study demonstrated 1-, 3-, and 5-year survival estimates of 86%, 65%, and 39%, respectively, for patients receiving an implantable cardiac pacemaker.

Disadvantages

Advances in pacemaker technology, products, and technique have reduced the complication rate associated with implanted pacemakers. A comparison of 2 large case reports suggests an apparent reduction of complications as veterinary cardiologists, and the residents they train, continue to gain experience with the procedure.

- **Complications:** In the 2 largest case studies, major complications occurred in 13% to 33% of patients (including lead dislodgement, sensing problems leading to syncope, infection associated with the implant, and ventricular fibrillation during implantation). A small percentage of patients develop "pacemaker syndrome," a progressive cardiac dysfunction (presumably associated with single-chamber pacing) that results in congestive heart failure. Minor complications (such as seroma formation at the pulse generator site) occurred in 11% to 31% of patients. The vein used to deliver the lead is sacrificed and should NEVER be used for venipuncture.

Lateral thoracic radiograph demonstrating dislodged pacing lead

- **Other disadvantages:** Implanted artificial cardiac pacemakers may be limited regionally because of the necessity for specialized training and equipment. Currently, there are fewer than 150 American College of Veterinary Internal Medicine board-certified cardiologists in the United States and fewer than 25 cardiology residency training programs. Availability of fluoroscopy, required in transvenous implantation for proper lead placement, is usually limited to specialty practices and university settings.

Economic Impact

Implantation of an artificial cardiac pacemaker typically costs the client $2000 to $4000, depending on the region of the country, length of hospital stay, and presence of complications. The patient is reevaluated 1 to 3 months after implantation so that the pulse generator and lead settings can be optimized for battery life conservation. Thereafter, the patient is usually evaluated annually. Progressive slowing of the preset heart rate or the development of clinical signs (such as syncope) may indicate the need for pacemaker revision (replacement of the pulse generator or battery or pacing lead). Lithium iodide batteries can have a lifespan of 5 to 12 years, depending on case scenario.

See Aids & Resources, back page, for references, contacts, and appendices.