



Epicardial pacemaker implantation in small animals

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Abstract Epicardial pacemaker implantation can be performed as a lone procedure or in combination with another thoracic or abdominal surgery. This article reviews the current literature and describes a minimally invasive approach for epicardial pacemaker implantation in small animals. The principal advantage of epicardial pacing is that it avoids contact with blood and intracardiac structures and thereby avoids uncommon but potentially devastating complications associated with endocardial pacemaker implantation. Epicardial pacing as a lone procedure can be accomplished via an abdominal transdiaphragmatic or minimal incision thoracotomy approach (minithoracotomy). A minithoracotomy offers the advantages of being less invasive and providing more direct access to the cardiac surface for suturing of epicardial electrodes. Epicardial pacing is a viable option for smaller animals, animals with pre-existing infections, animals at risk for thrombotic complications, or animals undergoing another thoracic or abdominal surgery. © 2018 Elsevier B.V. All rights reserved.

Introduction

In 1957, Dr. Clarence Walton Lillehei performed the first epicardial pacemaker implantation in a young patient after surgery for a ventricular septal defect [1,2]. Only 2 years later, Dr. Seymour Furman was the first to implant a transvenous

endocardial pacemaker [3]. The first epicardial pacemaker implantation in a dog was reported by Dr. James Buchanan in 1968 [4]. Dr. Musselman was the first to report a permanent transvenous pacemaker implantation in a dog in 1976 [5]. Over the years, endocardial pacing systems have gained favor over epicardial systems for lone pacemaker implantation owing to their less invasive nature compared with epicardial pacing which requires opening the thoracic cavity. However, endocardial

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pacing puts the lead in contact with blood and intracardiac structures, leading to a myriad of uncommon but potentially devastating complications. Epicardial pacing avoids contact with blood and intracardiac structures and can be considered for patients at higher risk for endocardial complications due to the patient size, pre-existing infections, or hypercoagulability. Epicardial pacing is particularly indicated when cardiac pacemaker implantation is necessary in patients undergoing other cardiothoracic or abdominal surgical procedures. In this case, the less invasive nature of endocardial pacing is no longer a particular advantage. Other indications for epicardial pacing have included neck pyoderma, transvenous pacemaker infection, endocarditis, immunosuppressive therapy, and arrhythmogenic right ventricular cardiomyopathy [6]. There is evidence in both normal dogs and dogs with complete atrioventricular block that pacing from the left ventricle might be associated with better cardiac systolic function compared with pacing from the right ventricular apex [7,8]. This could be an additional benefit of epicardial pacing, but this indication is not yet established.

Epicardial pacemaker implantation

Currently, the preferred lead for epicardial pacing in animals is the Medtronic® CapSure Epi steroid-eluting epicardial button (Fig. 1). The lead is available in unipolar (model# 4965) or bipolar (model#

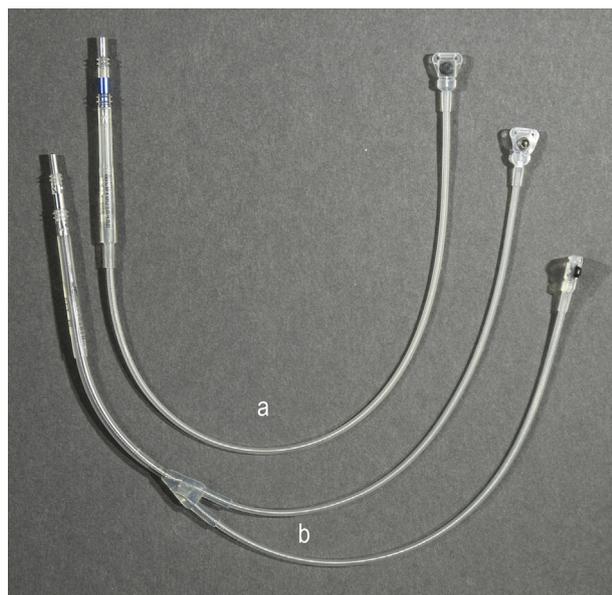
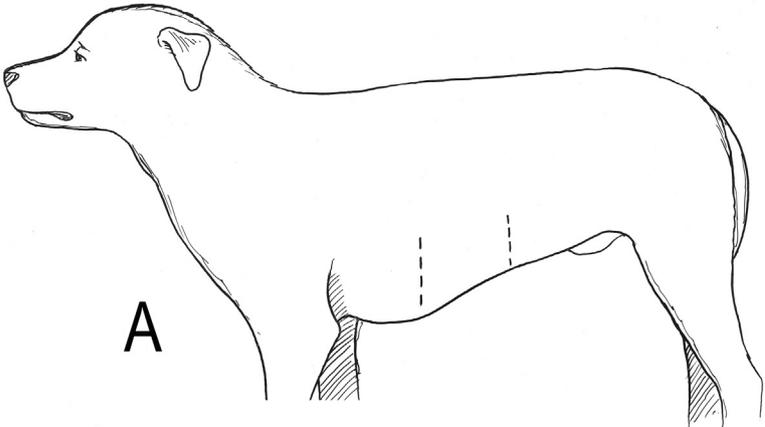


Figure 1 Unipolar (a) and bipolar (b) Medtronic® CapSure Epi steroid-eluting epicardial button-type pacing electrodes and lead wires.

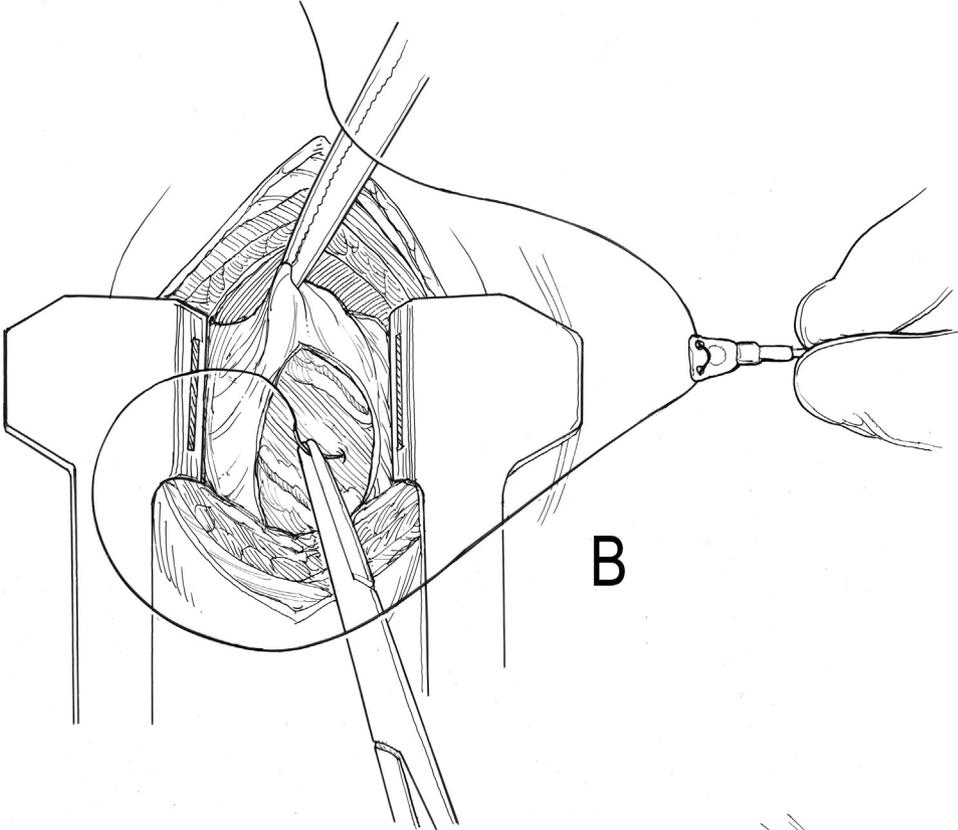
4968) configurations and comes in lengths ranging from 15 to 60 cm. Epicardial button electrodes can be implanted on either the atrium or the ventricle. In North America, these leads are available through the Companion Animal Pacemaker Repository (www.canpacers.org/). Suture-based fixation of epicardial buttons are generally preferred over sutureless-type fixation electrodes such as epicardial stab or screw-in type electrodes based on both reliability and versatility (i.e. atrial and ventricular placement) [9].

A couple of surgical approaches for lone implantation of an epicardial pacing system can be used. Historically, veterinary surgeons and cardiologists have favored a transdiaphragmatic approach with implantation of the generator in the lateral abdominal wall [6,10,11]. The principal advantage of this approach is the avoidance of a thoracotomy. This approach is very well described and illustrated in a recent publication by Visser et al. [6]. A potential disadvantage of this approach is that access to the cardiac apex can be difficult with this approach, particularly in the absence of significant cardiomegaly. Historically, this difficulty was somewhat avoided using older screw-in epicardial electrodes. However, for currently favored suture fixation epicardial buttons, poor cardiac access can result in an improperly or poorly implanted electrode, increasing the risk for lead dislodgement or failure to sense/capture. In a recent report, lead dislodgement was the leading major complication (15% of cases), using a transdiaphragmatic approach and sutured epicardial button electrodes [6]. A minimally invasive transxiphoid approach to gain better access to the cardiac apex from a ventral approach has also been described [12].

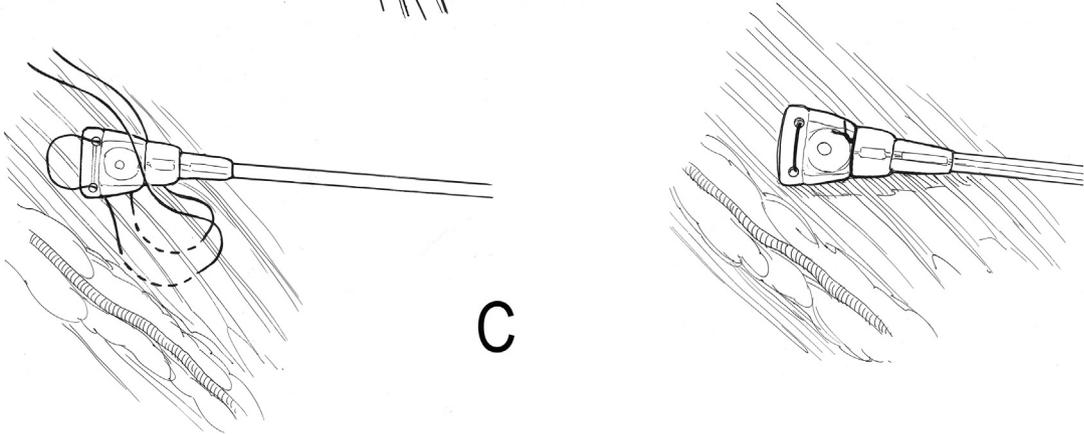
Currently, the author favors a minimally invasive (minimal incision) thoracotomy over the left cardiac apex for lone implantation of a single-chamber epicardial pacemaker with implantation of the generator through a separate incision in the lateral abdominal wall (Fig. 2A). The proximity of the cardiac apex to the thoracic wall makes it amendable to a minimally invasive thoracotomy (minithoracotomy), thereby diminishing the principal objection to standard thoracotomy, which is perceived to be more painful compared with an abdominal approach. This approach can be used in both dogs and cats. A 5- to 8-cm intercostal thoracotomy is performed over the cardiac apex in the ventral one-third of the left thorax (Fig. 2B). The optimal intercostal space to access the cardiac apex is determined from a lateral thoracic radiograph (typically the eighth intercostal space). The pericardium is opened exposing the apex of the left ventricle. A double-armed 5–0 polypropylene



A



B



C

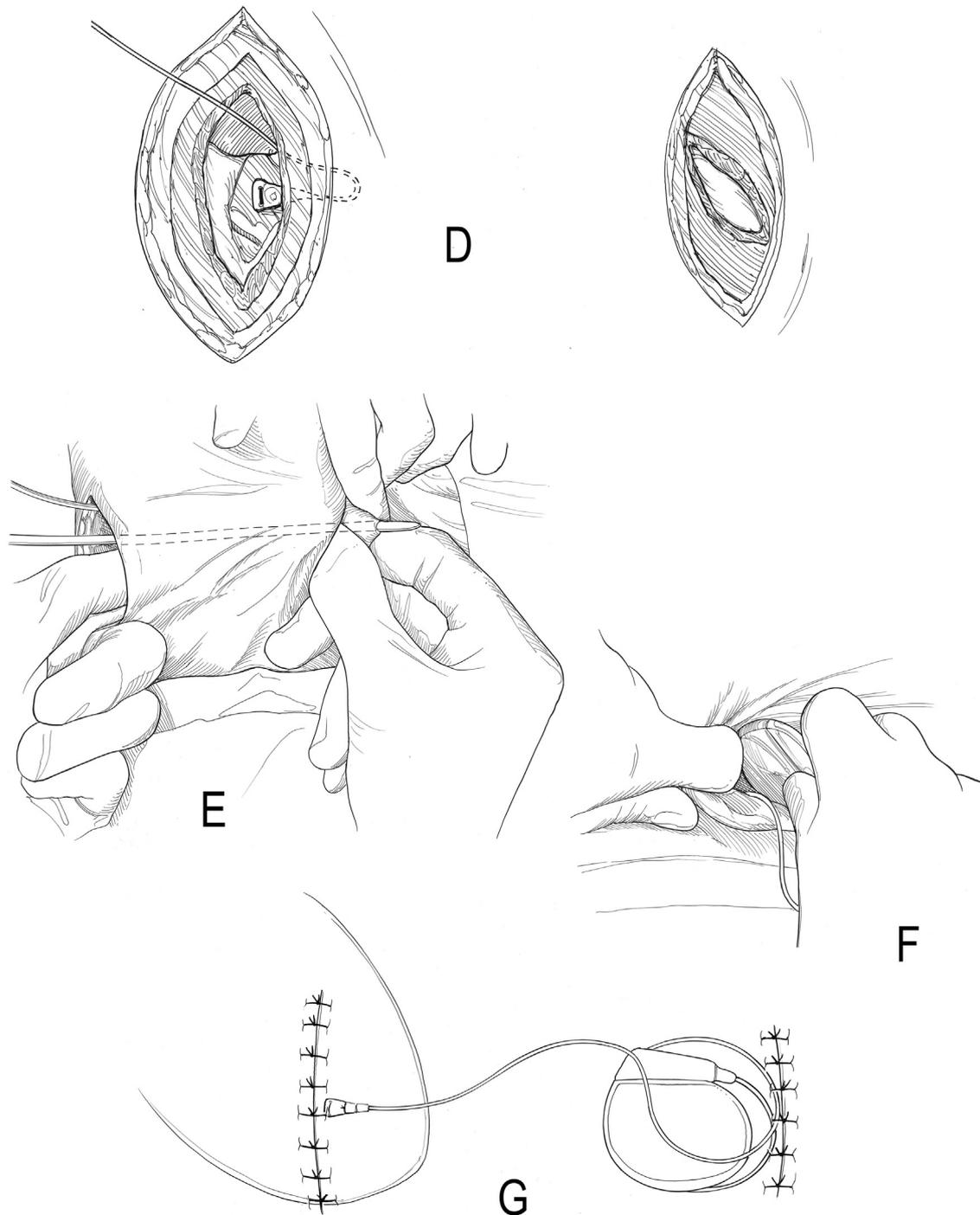


Figure 2 Epicardial pacemaker implantation via a minimal incision thoracotomy (A). A limited thoracotomy is performed over the left cardiac apex, and the pericardium is opened (B). A double-armed 5–0 polypropylene suture with 11-mm taper point needles is preplaced in the end holes of the button electrode. Parallel bites of the myocardium are taken in the cranial-to-caudal direction, avoiding major coronary vessels (C). The epicardial button is secured by tying the mattress suture over the neck of the epicardial button. A second incision is made in lateral cranial ventral abdominal wall (D). The external abdominal oblique muscle is opened parallel with its muscle fibers. The lead wire is tunneled through the costophrenic junction into the abdominal incision with the aid of a tunneling tool (E). The lead wire is connected to the pacing generator. The generator is placed into an abdominal pocket developed between the internal and external abdominal oblique muscles (F). A small thoracostomy tube is placed. Both incisions are closed routinely (G).

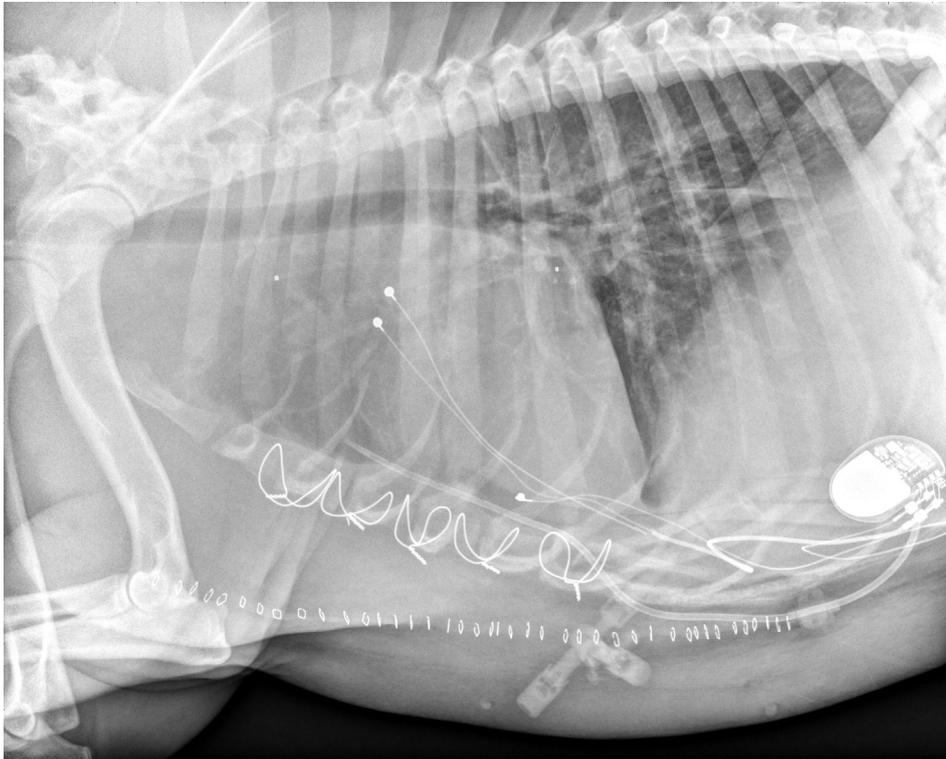


Figure 3 Radiograph of a 15-month-old cane corso dog that developed third-degree atrioventricular block immediately after surgical repair for tetralogy of Fallot. The dog underwent dual-chamber epicardial pacemaker implantation with bipolar atrial and unipolar ventricular electrode placement at the time of surgery.

suture with 11-mm taper point 3/8-shaped needles is passed through the end holes of the epicardial button in a mattress configuration (Fig. 2C). Deep parallel bites of the myocardium are taken with the suture needles directed in a cranial-to-caudal direction, resulting in a mattress-type suture pattern. Large coronary vessels are avoided. The epicardial button is secured by tying the mattress suture over the neck of the electrode. The procedure is repeated approximately 2 cm apart for a bipolar pacing electrode. Capture voltage threshold and lead impedance are determined to confirm adequate placement of the electrode. A second incision is made in the skin and external abdominal oblique muscle over the cranial lateral abdomen for implantation of the pacing generator (Fig. 2D). The lead wire is tunneled through the costophrenic junction using a tunneling tool or hemostatic forceps into the abdominal incision (Fig. 2E). The lead wire is connected to the pacing generator. The generator is placed into an abdominal pocket developed between the internal and external abdominal oblique muscles (Fig. 2F). A small thoracostomy tube^a is placed. Both incisions are closed routinely (Fig. 2G).

Dual-chamber epicardial pacemaker implantation via a standard right thoracotomy has been described in two dogs [13]. Fixation of epicardial buttons on the atrium was similar to the ventricle. The pacing generator was implanted into the lateral abdominal wall. Both cases had successful resolution of complete atrioventricular block, and one dog showed improved cardiac function after implantation. While lone dual-chamber epicardial pacemaker implantation requires a more invasive thoracotomy, the benefits of dual-chamber pacing may be justified in small animals with concurrent systolic dysfunction. If epicardial pacemaker implantation is combined with or becomes necessary after another cardiothoracic surgery, then epicardial pacemaker implantation can be accomplished from whatever thoracic approach is used for the other surgery. In this case, the less invasive advantage of endocardial pacing is negated. The same can be said for epicardial pacemaker implantation via a transdiaphragmatic approach for animals undergoing another abdominal surgery. Third-degree atrioventricular block is a recognized complication of several cardiac repairs, particularly repair of septal defects. Thus, it is prudent to be prepared for permanent epicardial pacemaker implantation when these surgeries are undertaken (Fig. 3).

^a 12 Ga or 14 Ga Chest Tube, Mila International, Inc. USA.

Discussion

Endocardial pacing is currently favored over epicardial pacing because implantation does not require opening of the thoracic cavity and thus is less invasive compared with epicardial pacing. However, endocardial pacing puts the lead in contact with blood and intracardiac structures, leading to a myriad of complications, including intracardiac thrombosis [14], right ventricular outflow tract obstruction [15,16], tricuspid stenosis [17–19], cranial or caudal vena caval fibrosis [14,20], cardiac perforation [14,21], chylothorax [22], and embolic pulmonary hypertension (personal observation). While these complications are considered uncommon, they tend to be devastating when they occur. Epicardial pacing avoids contact with blood and intracardiac structures and thus avoids the aforementioned endocardial-related complications. Epicardial pacing should be considered for animals with known or documented hypercoagulable states such as hyperadrenocorticism, idiopathic autoimmune hemolytic anemia, and protein-losing nephropathy. Epicardial pacing is generally considered the preferred option for cats and small dogs based on the size of available endocardial leads and a possible higher risk for endocardial complications. Epicardial pacing is considered the preferred option for permanent pacing in children due to physical growth, limited venous access, and risk of venous thrombosis [23]. Epicardial pacing should be considered whenever thoracic cavity or abdomen will be opened for another surgery.

In conclusion, permanent epicardial pacing remains a viable option in small animals for a variety of considerations, although clear guidelines for when epicardial pacing might be the preferred option have not been established. Electrode implantation for epicardial pacing can be accomplished via a transdiaphragmatic or minimal incision thoracotomy approach. The latter may provide more consistent access for suturing of electrodes, thereby decreasing the risk of lead dislodgement.

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