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Diagnostic imaging and pacemaker implantation in a domestic goat with persistent left cranial vena cava

Ravi Ranjan, MD, PhD^{a,*}, Derek Dossall, PhD^a, Layne Norlund, DVM^a, Koji Higuchi, MD, PhD^a, Joshua M. Silvernagel, BS^a, Aaron L. Olsen, DVM, PhD^b, Christopher J. Davies, DVM, PhD^b, Rob MacLeod, PhD^a, and Nassir F. Marrouche, MD^a

^aUniversity of Utah, Comprehensive Arrhythmia Research and Management Center, 30 North 1900 East, Salt Lake City, UT 84132, USA

^bUtah State University, School of Veterinary Medicine, Department of Animal Dairy and Veterinary Sciences, 5600 Old Main Hill, Logan, UT 84322, USA

Abstract

Difficulty was encountered with the insertion of a right atrial pacing lead via the left jugular vein during lead and pacemaker implantation in a clinically normal goat as part of an ongoing rapid atrial pacing - induced atrial fibrillation research project. Fluoroscopic visualization of an abnormal lead advancement path prompted angiographic assessment which revealed a persistent left cranial vena cava (PLCVC) and prominent coronary sinus communicating with the right atrium. Angiography facilitated successful advancement and securing of the pacing lead into the right side of the interatrial septum. Cardiac magnetic resonance imaging/magnetic resonance angiography (MRI/MRA) allowed further characterization of this rare venous anomaly. Even though PLCVC has been reported once in a goat, to the authors' knowledge this is the first report to include MRI/MRA characterization of PLCVC and prominent coronary sinus with successful cardiac pacemaker implantation using the PLCVC.

Keywords

Caprine; Magnetic resonance imaging/angiography

A clinically normal 42kg castrated male Boer goat (*Capra hircus*) was presented to the University of Utah for a right atrial pacing lead and neurostimulator^c (hereafter referred to as a pacemaker) implantation to induce atrial fibrillation (AF) by rapid atrial pacing (RAP), as previously described.¹ The goat was housed at Utah State University in Logan, UT, and was transported to and from the University of Utah in Salt Lake City, UT for pacemaker implantation and magnetic resonance imaging/magnetic resonance angiography (MRI/MRA) studies. The animal underwent a systematic physical examination upon receipt at the Utah State University research facility and again prior to implant surgery and pacing at the

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*Corresponding author. ravi.ranjan@hsc.utah.edu (R. Ranjan).

Conflicts of interest

None

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^cTrel 3 Neurostimulator, Medtronic Inc., Minneapolis, MN, USA.

University of Utah, including thoracic auscultation and electrocardiogram. Both examinations and ECGs were unremarkable with the exception of the discovery of a subcutaneous abscess on initial examination which was treated and resolved.

The animal underwent a baseline MRI/MRA study using propofol^d for anesthesia induction (4–6 mg/kg, IV) and isoflurane^e for maintenance anesthesia (1.5–3.0% isoflurane in 2.0–4.0 liters oxygen/min) two weeks prior to pacemaker implantation surgery. A MRI compatible monitoring system^f was used to continuously monitor animal heart rate and rhythm, respiratory rate, blood oxygen saturation, blood pressure, end-tidal carbon dioxide and body temperature. The persistent left cranial vena cava (PLCVC) and prominent coronary sinus were not identified at the time of baseline imaging because emphasis was placed upon cardiac chamber appearance and function, valve function, ventricular ejection fraction, and contrast medium diffusion and clearance (indicators of myocardial perfusion and injury, respectively).

Pacemaker implantation surgery was performed under the same anesthesia protocol as previously described. The skin of the left lateral mid-cervical region was shaved, prepared and draped for aseptic surgery using standard technique. A three-inch skin incision was made just dorsal and parallel to the jugular vein. A subcutaneous pocket large enough to contain the pacemaker was created dorsal to the jugular vein and the jugular vein was isolated. The jugular vein was accessed using a micropuncture needle^g and a guide wire^g was advanced through the needle toward the heart, followed by removal of the needle. A 5-French catheter introducer^g was advanced over the wire and inserted fully into the jugular vein. The micropuncture guide wire was exchanged for a standard 0.035", 45cm J-curve wire^g. Fluoroscopy was used to guide this process. When the J-curve wire was advanced toward the heart, the wire coursed toward the left atrium, rather than the cranial vena cava and right atrium as expected. Repeated attempts were made to guide the wire toward the right atrium but were unsuccessful. At this point, an angiogram was performed with 10mL of iopamidol^h to further visualize the cardiac great vessel anatomy. The angiogram revealed a PLCVC connecting to the coronary sinus and draining to the right atrium (Fig. 1A). Based on numerous reports in humans, in which successful placement of cardiac pacing and defibrillation devices was accomplished despite the presence of this congenital anomaly, we proceeded to implant the pacemaker lead.^{2,3} This was accomplished by passing the lead down the PLCVC and through the coronary sinus to the right atrium (Fig. 1B). Proper lead attachment and conductivity were confirmed by lead interrogation for conduction impedance, atrial capture threshold and AF inducibility testing using a portable pacing programmerⁱ.

The pacemaker and attached lead were then inserted into the prepared subcutaneous pocket and the surgical site was closed with standard technique. Rapid atrial pacing - induced AF was initiated two weeks later, with RAP parameters set at 4.0V pulse amplitude, 450µs pulse duration, 50Hz rate and 1 second ON (rapid pace)/1 second OFF.

Retrospective analysis of the baseline cardiac MRI/MRA scans confirmed the PLCVC and enlarged coronary sinus identified by fluoroscopic angiography at the time of pacemaker implantation (Fig. 2). Segmentation of MRA images was performed using computer

^dPropoFlo (propofol, 10 mg/ml), Abbott Laboratories, Abbott Park, IL, USA.

^eForane (isoflurane), Baxter Healthcare Corporation, Deerfield, IL, USA.

^fMedrad Veris MR Vital Signs Monitor, MEDRAD Inc., Warrendale, PA, USA.

^gCheck-Flo Performer Introducer Set, Cook Medical Inc., Bloomington, IN, USA.

^hISOVUE-370 (iopamidol 76%), Bracco Diagnostics Inc., Princeton, NJ, USA.

ⁱMedtronic CareLink Programmer – Model 2090, Medtronic Inc., Minneapolis, MN, USA.

software^j to produce three-dimensional reconstructions of right and left atria, PLCVC and the coronary sinus (Fig. 3).

All animal care and study procedures were conducted in accordance with the U.S. Animal Welfare Act and applicable federal, state and institutional regulations and policies under Institutional Animal Care and Use Committee (IACUC) - approved protocols at both institutions.

Discussion

Persistent left cranial vena cava is the most common congenital malformation of the thoracic venous drainage system in humans and canines, with a prevalence of 0.3–0.5% and 4.5% respectively.^{4,5} It generally results from failure of the left anterior cardinal vein to regress during embryonic development and is often associated with other congenital cardiac malformations.⁶ In most cases, the PLCVC drains into the right atrium via the coronary sinus and is clinically asymptomatic, although an increased incidence of arrhythmias occurs in this population. Right heart lead placement for cardiac pacemaker or cardioverter - defibrillator implantation can be very challenging in these cases.^{2,3,7} In the rare instances in which the PLCVC drains into the left atrium, it is often associated with other cardiac malformations and may result in chronic hypoxemia and episodic embolization.^{8,9}

Persistent left cranial vena cava has been reported in dogs, cats, horses, cattle, sheep and goats, in addition to the white panther and laboratory shrew.^{5,9–20} An extensive evaluation of 7,620 bovine hearts at necropsy reported a prevalence of distinct PLCVC of 76/7,620 (1.0%), and a prevalence of functional PLCVC comprised of other proximate veins (left costocervical, left azygous, left internal thoracic) of 135/7,620 (1.8%).⁹ Other congenital abnormalities commonly accompanying PLCVC were also reported, including atrial situs inversus, right aortic arch, absent coronary sinus and cervical ectopia cordis.⁹

In veterinary medicine, PLCVC is sometimes detected in association with more clinically significant cardiac malformations.^{11,20} Frequently, however, PLCVC is detected during cardiac pacemaker implantation surgeries for animals with cardiac arrhythmias. Since the majority of animals with PLCVC return blood to the right atrium via the coronary sinus (as in this case), most are not clinically affected, as was the case with the animal in this report.^{10,12,17}

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Abbreviations

AF	atrial fibrillation
MRA	magnetic resonance angiography
MRI	magnetic resonance imaging
PLCVC	persistent left cranial vena cava

^jSeg3D software was developed by the Scientific and Computing Institute at the University

RAP rapid atrial pacing

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Fig. 1. Thoracic fluoroscopy images at the time of pacemaker implantation surgery. (A) Left anterior oblique angiogram showing contrast in the PLCVC (arrows) and coronary sinus. (B) Same view as panel A after contrast washout with the pacing wire (arrows) coursing through the PLCVC and coronary sinus to the right atrium.

Fig. 2. Cardiac magnetic resonance angiogram images in transverse viewing plane of the thorax. (A) Case report goat at the level of the pulmonary arteries (PA) with PLCVC evident. (B) Normal goat at the same level as panel A showing an absence of any structure corresponding to the PLCVC. (C) Case report goat at the level of the coronary sinus showing a prominent coronary sinus. (D) Normal goat at the same level as panel C showing a normal caliber coronary sinus.

Fig. 3.

Segmented MR images showing the right atrium (RA - green), left atrium (LA - blue), and PLCVC and coronary sinus (CS - red). (A & C) Case report goat with PLCVC and partially visible coronary sinus showing in both views. (B & D) Similar views to panels A & C from a normal goat showing the coronary sinus and lack of any structure corresponding to a PLCVC. Panels A and B are left lateral views. Panel C and D are dorsolateral oblique views.