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Use of computed tomography and silicon endocasts to identify pulmonary veins with echocardiography

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Abstract The pulmonary veins were identified from the silicone endocast heart models of 19 dogs. Although variation in the number of the more peripheral veins on each specimen existed, all of the casts had a consistency with regards to the most proximal coalescence of the pulmonary veins as they entered the body of the left atrium. That is, the confluence of the veins formed three ostia at the atrial entry point that consisted of 1) right cranial and right middle pulmonary lobe veins; 2) right caudal, accessory, and left caudal pulmonary lobe veins; and 3) both the left cranial and left caudal pulmonary lobe veins of the left cranial lung lobe. The location of these structures identified by the 3-dimensional endocasts were then used to assist in the identification of the pulmonary veins using computed tomography of 2 dogs. Slices were made that approximated those commonly performed during echocardiographic examination. Understanding which pulmonary veins are seen by echocardiography in the different imaging planes will permit prospective evaluations of pulmonary vein size and abnormal flow patterns.

Introduction

The anatomy of the pulmonary veins in the dog has been described as more complex than in humans.[1]

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Abbreviations

Ao	aorta
Az	azygous vein
BT	brachyocephlic trunk
CdVC	caudal vena cava
CT	computed tomography
CS	coronary sinus
CrVC	cranial vena cava
GCV	great cardiac vein
LA	left atrium
LAur	left auricle
LPA	left pulmonary artery
LS	left subclavian
RA	right atrium
RPA	right pulmonary artery

Pulmonary veins identified for clarity by number

1	left cranial portion of left cranial lobe pulmonary vein
2	left caudal portion of left cranial lobe pulmonary vein
3	left caudal lobe pulmonary vein
4	accessory lobe pulmonary vein
5	right caudal lobe pulmonary vein
6	right middle lobe pulmonary vein
7	right cranial lobe pulmonary vein

The most proximal portion of the pulmonary veins can be seen by 2-dimensional echocardiography.[2] Although the anatomy and physiological responses of the pulmonary veins in the dog have been studied in the past,[3–8] more recent imaging modalities provide the opportunity to relate the anatomy to the echocardiographic planes. Using silicone injected hearts to create colored endocasts and contrast computed tomography (CT), the pulmonary veins and their connections to the lung lobes were compared. From these images the major pulmonary veins joining the left atrium were identified by echocardiography. This junction corresponded to the ostia (*ostia venarum pulmonalium*) of the pulmonary vein entrance to the left atrium. The purpose of this imaging report is to provide 3-dimensional anatomic images to guide the understanding of the pulmonary veins as seen with 2-dimensional echocardiography in the dog.

Image interpretation

The images shown in Figs. 1–3 were created using colored silicone heart endocasts from the anatomy library of the College of Veterinary Medicine, Cornell University. The 19 specimens were from various breeds prepared over more than 5 years for instruction of veterinary students. Samples were only from dogs for which the necropsy had been requested to ascertain the cause of death. It was not possible to ascertain if the dogs had normal hearts from these casts.

Each cast was examined with the goal of identifying the proximal portion of the major pulmonary veins entering the left atrium. Therefore, the identification of the ostia of the left atrium was not based on an opening seen in tissue, but on the vasculature. Although variation in the number of the more peripheral veins on each specimen existed, all of the casts had a consistency with regards to the most proximal coalescence of the pulmonary veins as they entered the body of the left atrium. This included the considerations of right versus left lung lobes and cranial versus caudal lung lobes. The structures surrounding the pulmonary veins were noted as landmarks (Figs. 1 and 2). The veins converged into 3 major areas corresponding to the ostia that were located on the roof of the left atrium. The cranial left ostia consisted of the left cranial (1) and caudal (2) branches of the left cranial lobe pulmonary vein. The caudodorsal ostia consisted of a confluence of the left caudal (3), accessory (4), and right caudal (5) lobe pulmonary veins. Variation in the exact location of the accessory pulmonary vein existed such that this vessel joined the right caudal lung lobe pulmonary vein before it appeared to meet the veno-atrial interface or the accessory pulmonary vein connected together with the right caudal lobe pulmonary vein at the ostia. The right ostia consisted of the right middle (6) and right cranial (7) lobe pulmonary veins. The right cranial lobe pulmonary vein converged as a single or double vessel.

A contrast CT scan was performed on a normal Beagle and Boxer with owner consent and with an approved Institutional Animal Care and Use Committee protocol. Both of these dogs had cardiac examinations including normal echocardiograms. The dogs were heavily sedated with propofol and placed in dorsal recumbency. Contrast imaging of the thorax was performed using a 16-slice CT[c] after intravenous infusion with 2 ml/kg of 350 iohexol[d]. Images were rendered and 3-dimensional reconstruction was performed with the commercial software provided with the scanner. Although the images of both dogs were studied by slicing the images in the various echocardiographic planes, only the images from the Boxer are shown (Figs. 3–5).

[c] Toshiba 16 slice. GE.
[d] Omnipaque, GE Healthcare.