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Cardiac-gated computed tomography angiography in three alpacas with complex congenital heart disease☆

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Abstract *Background:* The prevalence of congenital heart disease is higher in camelids than in other domestic species and complex defects, often involving the great vessels, are more frequently encountered in llamas and alpacas than in other species. Some of these complex defects can be difficult to accurately characterize via echocardiography, the most commonly used diagnostic imaging technique to evaluate the heart in veterinary patients. Contrast-enhanced, electrocardiogram (ECG)-gated computed tomography (CT) has proven utility for the evaluation of human patients with certain congenital heart defects, including those with conotruncal septation defects and other abnormalities involving the formation of the great vessels.
Methods: Three alpaca crias, 4 days, 5 weeks and 14 months of age were clinically evaluated and subjected to a complete color-flow Doppler echocardiogram and a

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contrast-enhanced ECG-gated CT.
Results: These alpacas exhibited a variety of clinical findings including lethargy, failure to thrive, exercise intolerance, heart murmur, and/or respiratory difficulty. All three crias were subsequently diagnosed with complex cardiac defects including pulmonary atresia with a ventricular septal defect (VSD), a truncus arteriosus with a large VSD, and a double outlet right ventricle with a large VSD and aortic hypoplasia. In each case, the diagnosis was confirmed by postmortem examination.
Conclusion: Color flow echocardiographic evaluation identified all of the intra-cardiac lesions and associated flow anomalies but contrast-enhanced ECG-gated CT permitted more accurate assessment of the morphology of the extracardiac structures and permitted a more precise determination of the exact nature and anatomy of the great vessels.
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Abbreviations

C	celsius
CHD	congenital heart disease
CT	computed tomography
DORV	double outlet right ventricle
ECG	electrocardiography
MAPCA	main aortopulmonary collateral arteries
MDCT	multi-detector computed tomography
OSU VTH	oregon state university veterinary teaching hospital
PDA	patent ductus arteriosus
VSD	ventricular septal defect

Congenital heart diseases (CHDs) are the most common cardiac disorders in camelids with a reported prevalence of 1.6—3.5%.[1—4] There is a predisposition for complex cardiac defects involving the aorta and pulmonary arteries in alpacas and llamas, including vascular ring anomalies, tetralogy of Fallot, persistent truncus arteriosus, pulmonary atresia with ventricular septal defect (VSD; also referred to as 'pseudo-truncus'), transposition of the great vessels, and double outlet right ventricle (DORV).[1—7] Such defects are of particular interest for investigators interested in the role of the second heart field in conotruncal septation and the processes of abnormal development leading to similar defects in children.[8,9] The first heart field gives rise to the linear heart tube, left ventricle and part of the inflow region of the heart. The second heart field gives rise to the right ventricular and outflow tract myocardium as well as part of the inflow area. The cells of the second heart field area are recruited during the process of heart tube elongation and looping. Derangements during recruitment of the second heart field cells or defects in the second heart field—derived myocardial outflow tract wall are suspected to strongly contribute to a variety of congenital heart defects.[10,11] In this regard, camelids may prove to be a valuable animal model for studying the anatomic variations of such defects and the genes that participate in the regulation of the activities of the cells comprising the second heart field.[12] Hence, the identification and characterization of these defects is likely to be of increasing importance.

Echocardiography is the most commonly used imaging technique to evaluate domestic animals with CHD and is particularly helpful for evaluating structural changes in the heart and identifying intra-cardiac flow disturbances. Despite these attributes, echocardiographic studies provide only a limited view of the great vessels and other extra-cardiac structures because of the presence of aerated lungs and limited acoustic windows. These constraints can be surmounted by magnetic resonance imaging and contrast-enhanced computed tomography (CT), but both techniques require general anesthesia for the evaluation of animal subjects. Computed tomography is becoming more readily available for the evaluation of veterinary patients and recent developments in technology have significantly improved its role in the evaluation of patients with cardiac disease.[13] Newer scanners can acquire thoracic images faster than the heart rate, facilitating the creation of motion-free images of the heart and vasculature over the duration of the cardiac cycle. As a result, electrocardiography (ECG)-gated CT has become an important supplementary technique to evaluate human patients with complex CHD.[14—16] Not only does ECG-gated CT provide the high spatial resolution needed to evaluate the heart, but it also