Journal of Veterinary Cardiology (2017) ■, ■–■

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Journal of Veterinary Cardiology
ESVC

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Comparison of cardiac measurements by multi-detector computed tomography angiography and transthoracic echocardiography in English bulldogs

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Received 11 June 2017; received in revised form 13 September 2017; accepted 18 October 2017

KEYWORDS
Cardiac angiography;
Retrospective ECG-Gating;
Dual source;
Canine;
Veterinary

Abstract *Introduction:* Transthoracic echocardiography (TTE) is the primary tool for the assessment of cardiac structure and function in dogs but is challenging in English bulldogs due to dorsoventral compression of the thorax, obesity, and narrow intercostal spaces. Multi-detector computed tomography angiography (CTA) may overcome the conformational obstacles of cardiac imaging in this breed.
Animals: Eleven client-owned English bulldogs.
Materials and Methods: Prospective clinical trial with paired analysis of TTE and CTA studies.
Results: Eight of the 25 linear cardiac dimensional measurements were significantly different between TTE and CTA ($p<0.033$). Intraobserver agreement was strong with average coefficients of variation (CV) of 5.34% for TTE and 2.50% for CTA. Interobserver agreement CV averaged 6.5% for TTE and 8.75% CTA. Ejection fraction, stroke volume, and end-systolic volume were significantly different between modalities (all $p<0.002$). No significant difference was present between end-diastolic

This study was presented in poster at the American College of Veterinary Radiology meeting in Minneapolis, MN (October 2015).

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https://doi.org/10.1016/j.jvc.2017.10.003
1760-2734/Published by Elsevier B.V.

volume for TTE compared with CTA.
Discussion: High-quality cardiac angiographic studies were accomplished using CTA without the use of general anesthesia in English bulldogs. Multi-detector computed tomography angiography and TTE are not interchangeable modalities in the clinical setting.
Conclusion: Multi-detector-CT ECG-gated cardiac angiography is possible in sedated, non-intubated English bulldogs. Differences were found between some cardiac dimensions as measured by TTE in the awake dog and compared with sedated CTA, indicating the two methodologies are not equivalent. Sedated, non-intubated CTA yielded high-quality imaging with strong intraobserver and interobserver measurement repeatability in English bulldogs.
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List of abbreviations

CMR	cardiac magnetic resonance
CV	coefficients of variation
CTA	multi-detector computed tomography angiography
ECG	electrocardiogram
EDV	end-diastolic volume
EF	ejection fraction
ESV	end-systolic volume
FW	free wall
IBMD	information-based measurement of disagreement
ICC	intraclass correlation
IVS	interventricular wall
LA	left atrium
LV	left ventricle
MDCT	multi-detector computed tomography
MPR	multi-planar reconstruction
SV	stroke volume
TTE	transthoracic echocardiography

Introduction

A functional and structural analysis of the left ventricle (LV) and left atrium (LA) is critical for diagnosis and therapy planning in animals with left-sided heart disease. Routine techniques used to screen for heart disease in dogs include a combination of thoracic radiography and transthoracic echocardiography (TTE). A major limitation of radiography is that cardiac chamber size is indirectly assessed. Border effacement between myocardium and the chamber lumen results in a low sensitivity for mild chamber enlargement. Radiography also lacks of temporal evaluation since images are a representation of a single static moment rather than a functional assessment [1,2]. Transthoracic echocardiography is highly operator dependent and commonly performed by specialists with advanced training to investigate for chamber dilation, valvular dysfunction, and diminished functional parameters [3–6]. However, TTE is limited by adequate imaging windows and patient compliance [7]. The ideal diagnostic test needs to incorporate the positives of these two modalities; providing accuracy, reliability, and repeatability [2,8]. Currently in dogs, chamber volumes and functional parameters like ejection fraction (EF) or stroke volume (SV) are calculated from linear measurements obtained with two-dimensional TTE. The calculations are vulnerable to extrapolation errors because they rely heavily on geometric assumptions to generate structural and functional data [9,10].

The English bulldog breed has a number of genetic issues that complicate standard thoracic radiographic interpretation and ease of TTE acquisition. Radiographic interpretation is also often complicated by respiratory motion if there is brachycephalic obstructive airway syndrome, as well as poor inflation of the lungs resulting in decreased margin conspicuity of the cardiac silhouette. The bulldog thorax is dorsoventrally compressed with a high frequency of hemivertebrae making it difficult to apply typical measurement methods [11]. Narrow intercostal spaces limit the acoustic window making accurate echocardiographic measurements imprecise and possibly amplifying inaccurate measurements [7,12–14].

Cross-sectional imaging overcomes the obstacles of radiography and TTE. Cardiac magnetic resonance imaging (CMR) is considered the gold standard modality for assessing chamber size and ventricular function in human medicine [15–17]. The major limiting factor for utilization of CMR in veterinary medicine is access to a high field magnet with electrocardiography (ECG)-gating technology, as well as long acquisition times under general anesthesia. Multi-detector computed tomography (MDCT) with angiography (CTA) has a

Please cite this article in press as: Hostnik ET, et al., Comparison of cardiac measurements by multi-detector computed tomography angiography and transthoracic echocardiography in English bulldogs, Journal of Veterinary Cardiology (2017), https://doi.org/10.1016/j.jvc.2017.10.003