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Left atrial volume and phasic function in clinically healthy dogs of 12 different breeds

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ABSTRACT

The left atrium (LA) of the heart is a validated marker of clinical and subclinical cardiovascular disease. Since the LA is a three-dimensional structure, volume-based methods of chamber quantification might be more accurate than linear methods. The aims of this study were to establish the feasibility and reproducibility of biplane two-dimensional echocardiographic LA volume measurements and to provide reference ranges for LA volume and phasic function in adult dogs ($n = 237$) without cardiovascular disease. The study also assessed the effects of bodyweight (BW), breed, sex, age and heart rate (HR) on LA volume and function. The biplane area–length method was used to calculate LA volumes from the left apical four- and two-chamber views.

LA volume and function were correlated with body size and there were significant breed differences. For dogs of all sizes and breeds, LA maximal volume had a 95th percentile of 0.92 mL/kg. There was no correlation between age or sex and LA volume or LA reservoir function, but conduit function decreased and booster pump function increased with age. LA volume and function varied with HR. LA size was calculated using the biplane area–length method, with good reproducibility and little inter-observer variability. The reference ranges presented for LA volume and function in healthy dogs could be used to refine the diagnostic criteria for the assessment of LA enlargement and altered function by conventional echocardiography.

Introduction

The left atrium (LA) of the heart acts as a reservoir for blood during ventricular systole; it serves as a conduit for blood passively transiting from the pulmonary veins to the left ventricle (LV) during early ventricular diastole and, in late ventricular diastole, the LA becomes a muscular pump to complete the process of LV filling (Abhayaratna et al., 2006). Changes in LA size or function might indicate the presence and severity of heart disease (Järvinen et al., 1994; Borgarelli et al., 2008).

LA size can be measured non-invasively by echocardiography and thus can be a convenient marker of cardiovascular health. Traditionally, LA size is determined using linear M-mode or two-dimensional (2D) measurements (Boon et al., 1983; Rishniw and Erb, 2000). The ratio of the aortic root diameter to the LA short axis 2D-dimension is the parameter most commonly used in veterinary clinical practice (Hansson et al., 2002). Since the LA is three-dimensional (3D) and its enlargement can result in an asymmetrical geometry, measurement of a single linear diameter or area might not accurately reflect actual LA size (Lester et al., 1999; Tsang et al., 2006; Tidholm et al., 2011). Tidholm et al. (2011) compared four different linear 2D methods of estimating LA size with real-time 3D volumes in dogs. Real time 3D methods theoretically could provide the most accurate measurements, but they are time consuming and specialised equipment is needed.

The Guidelines and Standards Committee of the American Society of Echocardiography recommend quantification of LA size by biplane 2D echocardiography using either the method of discs (Simpson's rule) or the biplane area–length method from the left apical four- and two-chamber views (Lang et al., 2005).

In veterinary medicine, no standardised method for LA volume measurements has been widely adopted and, to date, no reference values for LA volume derived by biplane 2D echocardiography in healthy dogs have been formally reported. This study aimed: (1) to assess the feasibility and reproducibility of measuring LA volume with 2D echocardiography using the biplane area–length method; (2) to establish reference intervals for LA volume and phasic function in dogs without cardiovascular disease and; (3) to assess the effects of breed, sex, age, bodyweight (BW) and heart rate (HR) on LA volume and function in dogs.

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Materials and methods

Study population

This prospective cross-sectional study included privately owned dogs of 12 different breeds: Chihuahua, Border terrier, Dachshund, Cavalier King Charles spaniel, Petit Basset Griffon Vendeen, Whippet, Boxer, Dalmatian, Labrador retriever, Newfoundland, Great Dane and Irish wolfhound. The dogs were recruited from dogs visiting the University of Copenhagen veterinary hospital for unrelated reasons and through cooperation with the Danish Kennel Club. Dogs were considered to be healthy on the basis of the absence of owner-reported clinical signs and unremarkable serum biochemical results, together with normal findings on physical examination, electrocardiography (ECG), M-mode, 2D and Doppler examinations.

The study was approved by the Ethical Committee at the Department of Clinical Veterinary and Animal Sciences, University of Copenhagen (REF: 18/2008).

Echocardiography

All examinations were performed by the same experienced cardiac sonographer with a Vivid 7 ultrasonographic system equipped with a 4M MHz and a 5S MHz phased-array transducer. The echocardiographic images were stored as digital data for later analysis using the Echo PAC for PC, 7.0 (GE Healthcare). The unsedated dogs were gently restrained and examined from below in right and left lateral recumbency. Each dog underwent a complete echocardiographic examination, which included transthoracic 2D, M-mode, spectral and color flow Doppler imaging with continuous ECG monitoring according to recommendations (Thomas et al., 1993; Quinones et al., 2002). Measurements were made on three consecutive cardiac cycles and mean values were used in the statistical analysis.

Volume measurements

The left apical four- and two-chamber views were used for calculating volume measurements (Fig. 1A–D). These views were obtained with the dog in left lateral recumbent position. The left apical two-chamber view was obtained from a standard left apical four-chamber view (Thomas et al., 1993). In order to avoid a tilted view, the transducer was rotated 90° counterclockwise and angled toward the neck. The right chambers should not be seen in this view. Subtle adjustments were sometimes needed to qualitatively maximise LA size with no foreshortening and to obtain clear outlines of the chamber at end-diastole and end-systole.

All LA volume measurements were calculated using the biplane area–length method (Lang et al., 2005):

$$\text{LA volume} = \frac{8}{3\pi}([A1 \times A2]/L) = (0.85 \times A1 \times A2)/L$$

where $A1$ and $A2$ represent the planimetered LA area acquired from the apical four- and two-chamber views and L is the length. The LA area was traced along the inner border of the atrial wall, excluding the confluence of the pulmonary veins and the LA appendage. A straight line connecting both the hinge points of the mitral leaflets was taken as the border to the LV, thus excluding the funnel of the mitral valve leaflets from the LA tracing. LA length was measured from the centre of the mitral annular plane to the superior border of the chamber (Lang et al., 2005; Leung et al., 2008). Length was measured in both the four- and two-chamber view and the average of these two length measurements was used in the formula (Ujino et al., 2006). The LA volumes were measured at three points in the cardiac cycle: (1) just before mitral valve opening (maximal LA volume); (2) at the onset of the P-wave on the electrocardiogram (preatrial contraction volume, LA P-volume), and (3) at mitral valve closure (minimal LA volume).

To describe the three phases of LA function, different variables were calculated according to Spencer et al. (2001) and Nikitin et al. (2003) (Fig. 2).

LA reservoir function was assessed using the following equations:

$$\text{LA total emptying volume (LAEV)} = \text{Maximal LA volume} - \text{Minimal LA volume}$$

$$\text{LA expansion index} = \text{LAEV/Minimal LA volume } (\%)$$

LA conduit function was assessed by using the following equations:

$$\text{LA passive emptying volume (LAPEV)} = \text{Maximal LA volume} - \text{LA P-volume}$$

$$\text{LA passive emptying \% total emptying (LAPE)} = \text{LAPEV/(Maximal LA volume} - \text{Minimal LA volume) } (\%)$$

LA active booster pump function was evaluated using the following equations:

$$\text{LA active emptying volume (LAAEV)} = \text{LA P-volume} - \text{Minimal LA volume}$$

$$\text{LA active emptying \% total emptying (LAAE)} = \text{LAAEV/(Maximal LA volume} - \text{Minimal LA volume) } (\%)$$

To assess the reliability of the volume measurements, 10 dogs were randomly selected for repeat measurements by the same reader and a second reader. Areas

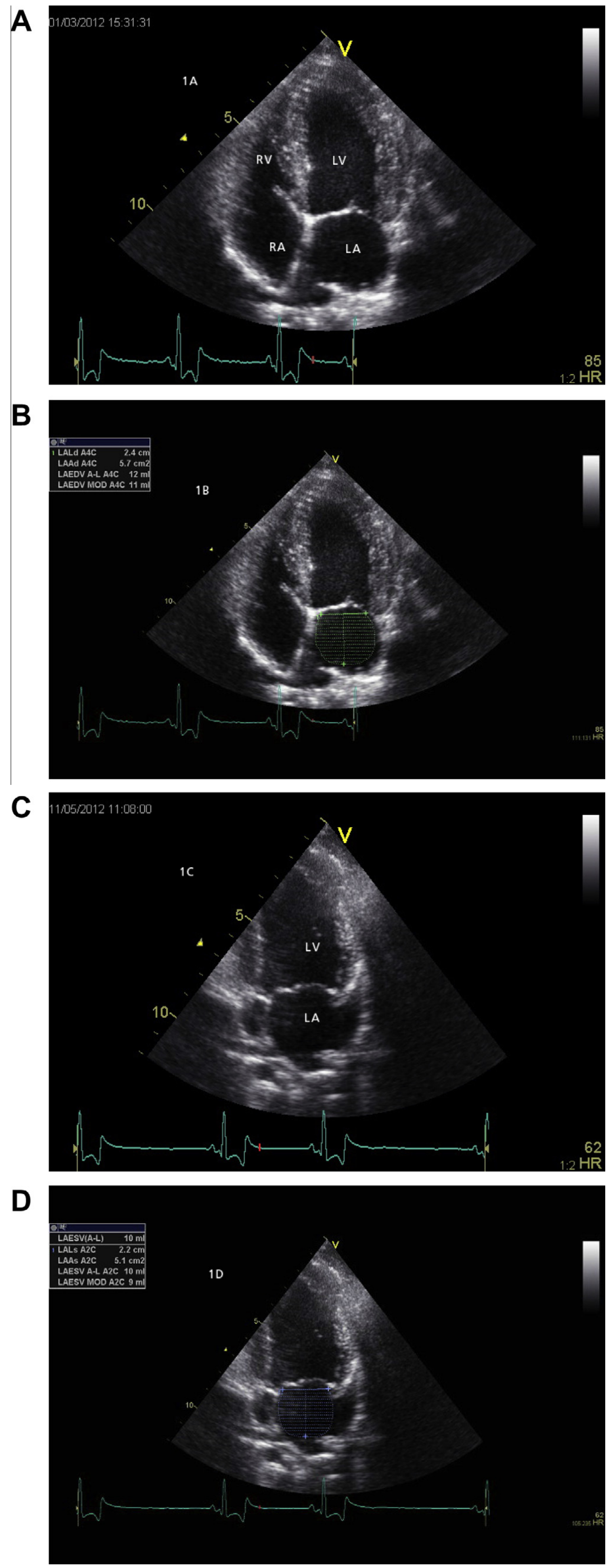

Fig. 1. Measurement of left atrial (LA) volume from the left apical four-chamber (A and B) and two-chamber views (C and D) using the biplane area–length method at ventricular end systole (maximum LA size). The LA area is traced along the inner border of the atrial wall, excluding the confluence of the pulmonary veins and the LA appendage (B and D). LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.