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The times they are a-changin': Two-dimensional aortic valve measurements differ throughout diastole

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Abstract *Introduction:* Diastolic aortic valve measurements are used to obtain weight-independent cardiac ratiometric indices. However, whether clinically important variations in valve measurements occur during diastole remains undetermined.
Animals: One hundred sixty-three dogs and 40 cats; a mixture of healthy animals and patients with heart disease.
Materials and methods: Aortic valve diameter and area were measured at three time-points: early diastole {Ao_{MAX}}, during the P-wave {Ao_P} and at end-diastole {Ao_{MIN}}. Measurement beat-to-beat variability was determined. Difference plots were generated for each measurement pair. Aortic measurements were compared by repeated measures analysis of variance.
Results: In dogs, normalised aortic diameters showed a fixed bias of approximately 14% for Ao_{MAX}-Ao_{MIN}, 6% for Ao_{MAX}-Ao_P and 8% for Ao_P-Ao_{MIN}. In cats, the aortic diameter and area biases were all less than 2.5% and less than 7% respectively. Ao_{MAX} was the largest measurement in 78% patients and AoMIN was the smallest measurement in 73% patients. In dogs, AoMAX > AoP > AoMIN ($p < 0.0001$). Median within-patient measurement variability was 5% for linear dimensions and 8% for area measurements in dogs and 4.5% for linear and 10.4% for area in cats.
Discussion: Aortic measurements in dogs differ significantly throughout diastole,

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with Ao(A)MAX > Ao(A)P > $Ao(A)_{MIN}$. These differences could clinically impact cardiac ratiometric indices. The difference in cats is less than the within-patient measurement variability and unlikely to be of clinical significance.
Conclusions: Operators should adopt a single diastolic time-point for measurement of the aorta to ensure consistency in measuring and reporting in echocardiography.

Abbreviations

Ao	aorta
AoAmax	aortic area, start of diastole
AoAmin	aortic area, end of diastole
AoAp	aortic area, peak of P-wave
Aomax	aortic dimension, early diastole
Aomin	aortic dimension, end of diastole
AoP	aortic dimension, peak of P-wave
LA	left atrium

Echocardiographic aortic (Ao) valve measurements are routinely obtained during cardiac evaluation of patients. The aortic valve is not affected by most common cardiac disorders. Therefore, clinicians use aortic measurements to create weight-independent ratiometric estimates of cardiac dimensions, particularly the left atrium (LA),[1–4] by dividing the cardiac dimension of interest by the aortic dimension (e.g. LA:Ao). These ratios allow clinicians to make comparisons within and between individuals and standardise intervals or thresholds for categories of severity of cardiac pathology. Furthermore, researchers often use ratiometric indices in pre-defined enrolment criteria for study inclusion.[5–10]

In humans, the aortic valve dimensions change in diastole[11] and these changes are measurable echocardiographically.[12] Recommended guidelines have been published for the technique of acquiring[13] and measuring echocardiographic studies in veterinary medicine,[2,3,14] including timing of measurements. Most studies in veterinary patients that examine measurements of the LA and aorta have measured the aortic valve in early diastole immediately upon valve closure,[2,3,15–20] whereas others use end-diastole[21] or have failed to specify the timing of the measurements.[22] However, some clinicians prefer to use a different diastolic time-point, such as the mid-point of the P-wave, because the resolution of the measured landmarks improves as diastole progresses.[d] In addition, in two large meta-analyses,[4,23] aortic measurements were obtained via M-mode but exact timing of the measurement was not described as the data were sourced from many different investigators using differing techniques. Consequently, there is currently no consensus about the point in diastole at which aortic valve measurements should be obtained. Furthermore, whether aortic measurements differ throughout diastole in dogs and cats remains unproven. If clinically relevant differences exist, measurements obtained at different diastolic time-points would not be interchangeable.

We sought to compare two-dimensional echocardiographic linear and area aortic dimensions at three distinct diastolic time-points to determine if differences exist between these measurements and if they are interchangeable. Furthermore, to provide a clinical context to our study, we sought to examine the impact of any differences on clinical interpretations of LA size.

Animals, materials and methods

Dogs and cats presented to the investigators' clinics from April 2013 to December 2014 for echocardiographic evaluation were prospectively enrolled in the study. Suboptimal images and those obtained from animals with any disease which created aortic valve abnormalities (such as aortic valve stenosis, aortic endocarditis and so on) were excluded from analysis. Animals with atrial fibrillation or other persistent non-sinus arrhythmias were also excluded. Animals with other cardiac diseases were not excluded. The study population consisted of normal and diseased animals: 59% of dogs and 67% of cats had cardiac disease. As the

[d] Virginia Luis Fuentes, personal communication.