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Tricuspid annular plane systolic excursion-to-aortic ratio provides a bodyweight-independent measure of right ventricular systolic function in dogs

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Abstract *Objectives:* To evaluate whether tricuspid annular plane systolic excursion (TAPSE) can be normalized to aortic valve (Ao) measurements in dogs. To determine TAPSE:Ao reference intervals for healthy dogs and examine diagnostic performance of TAPSE:Ao in dogs with pulmonary hypertension (PH).
Animals: One hundred and thirty-seven healthy adult dogs; 115 dogs with myxomatous mitral valve disease (MMVD) but no PH; 91 dogs with PH.
Methods: A combined prospective and retrospective study. Full echocardiographic evaluations were performed on all dogs; TAPSE was indexed to Ao to produce a unitless TAPSE:Ao. Reference intervals for TAPSE:Ao were generated, and TAPSE:Ao was regressed on tricuspid regurgitant jet velocity in dogs with PH and on LA:Ao in dogs with MMVD without PH. Diagnostic test analysis was used to examine the ability of TAPSE:Ao to identify severe PH. An adjusted TAPSE:Ao (TAPSE:$Ao_{(adj)}$) was derived to account for MMVD in dogs with PH.

The preliminary results of this study were presented at the 2016 ECVIM Congress in Goteborg, Sweden.

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Results: The ratio, TAPSE:Ao, removed the effect of bodyweight from TAPSE measurements. Healthy dogs had TAPSE:Ao > 0.65. The ratio, TAPSE:Ao, showed a linear negative relationship with tricuspid regurgitation velocity and positive relationship with LA:Ao. The adjusted ratio, TAPSE:$Ao_{(adj)}$, increased the sensitivity of diagnosis of PH in dogs with moderate-severe MMVD without affecting the diagnosis of PH in dogs with PH and with no or mild MMVD.
Conclusions: The ratios, TAPSE:Ao and TAPSE:$Ao_{(adj)}$, are a bodyweight-independent means of assessing right ventricular systolic function in dogs and for identifying severe PH in dogs with or without MMVD.

Abbreviations:

Ao	aorta
LA	left atrium
LA:Ao	ratio of the left atrial dimension to the aortic annulus dimension
MMVD	myxomatous mitral valve disease
PH	pulmonary hypertension
TAPSE	tricuspid annular plane systolic excursion
TAPSE:Ao	ratio of the tricuspid annular plane systolic excursion-to-aortic annulus dimension
TAPSE:$Ao_{(adj)}$	ratio of the tricuspid annular plane systolic excursion-to-aortic annulus dimension corrected for mitral valve disease severity
nTAPSE	tricuspid annular plane systolic excursion normalized to bodyweight
wTAPSE	weight-adjusted tricuspid annular plane systolic excursion
$wTAPSE_{(adj)}$	weight-adjusted tricuspid annular plane systolic excursion corrected for mitral valve disease severity

Tricuspid annular plane systolic excursion (TAPSE) is an echocardiographic measure of right ventricular systolic function [1,2]. It is obtained from the left apical 4-chamber view and measures the apical displacement of the lateral portion of the tricuspid annulus during ventricular systole [1]. Studies have demonstrated that this displacement is reduced in dogs with primarily severe PH (PH) and with right ventricular myocardial failure [1]. One study reported decreased survival in boxer dogs with arrhythmogenic right ventricular cardiomyopathy and reduced TAPSE [3]. Two studies found disparate effects of mitral valve disease on TAPSE—one found that TAPSE did not predict PH in dogs with mitral valve disease [4], whereas the other found that TAPSE increased with worsening mitral valve disease and with worsening PH in dogs with mitral valve disease [5]. Finally, two studies found that TAPSE decreased in cats with HCM proportionally to the severity of the left heart disease [6,7].

In humans, TAPSE has a normal range of 1.5—2 cm [8,9]. However, in dogs and in children, the measurement scales non-linearly with body size, requiring clinicians to refer to reference tables or perform calculations to estimate TAPSE reference values [1,10].

Since TAPSE is a linear measurement that scales with bodyweight to approximately the 1/3 power [1], one group of investigators attempted to correct for the effect of body size by normalizing to bodyweight raised to the 1/3 power [4]. However, these investigators did not provide reference thresholds for the normalized TAPSE (nTAPSE). On the other hand, indexing TAPSE to another linear measurement should produce a unitless bodyweight-independent reference interval, similar to left atrium-to-aorta ratio (LA:Ao). This TAPSE-to-aorta ratio (TAPSE:Ao) should have a single lower reference limit against which all dogs can be compared. Similarly, using the approach proposed by Brown et al. [11], a weight-adjusted TAPSE (wTAPSE) should be similar to TAPSE:Ao and nTAPSE.

Therefore, we sought to examine the relationship of TAPSE and bodyweight in healthy dogs and to create a TAPSE:Ao and wTAPSE, which, we hypothesized, would both be independent of bodyweight. We then sought to create a lower reference limit that clinicians could easily remember when measuring TAPSE:Ao (or wTAPSE or nTAPSE) in their patients. In addition, we examined the relationship of TAPSE:Ao (and wTAPSE and nTAPSE) in the presence of

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