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Mitral Annular Plane Systolic Excursion and Tricuspid Annular Plane Systolic Excursion in Cats with Hypertrophic Cardiomyopathy

I. Spalla, J.R. Payne, K. Borgeat, A. Pope, V. Luis Fuentes, and D.J. Connolly

Background: Left ventricular (LV) systolic dysfunction is associated with increased risk of death in cats with hypertrophic cardiomyopathy (HCM). Mitral and tricuspid annular plane systolic excursion (MAPSE and TAPSE, respectively) are measures of longitudinal systolic function and are reduced in human patients with HCM.

Hypotheses: Cats with HCM have lower MAPSE and TAPSE compared to control cats; lower MAPSE and TAPSE are associated with the presence of congestive heart failure (CHF) and reduced survival time.

Animals: 64 cats with HCM and 27 healthy cats. Forty-five cats with HCM were not showing clinical signs, and 19 had CHF.

Methods: Retrospective study. Anatomic M-mode from the left apical 4-chamber view was used to record MAPSE from the free wall (MAPSE FW) and septum (MAPSE IVS) and TAPSE.

Results: Compared to controls, cats with HCM had lower MAPSE IVS (controls 5.2 [4.6–5.6] mm, asymptomatic HCM 4.7 [4.1–5.2] mm, HCM with CHF 2.6 [2.5–3.2] mm, $P < .001$), MAPSE FW (controls 5.9 [5.3–6.2] mm, asymptomatic HCM 4.7 [4.1–5.1] mm, HCM with CHF 2.8 [2.4–3.2] mm) and TAPSE (controls 8.6 [7.4–10.2] mm, asymptomatic HCM 7.2 [6.3–8.2] mm, HCM with CHF 4.6 [4.1–5.4] mm), with the lowest in the CHF group. Univariate survival analysis showed a shorter survival in cats displaying lower MAPSE IVS, MAPSE FW, and TAPSE.

Conclusions and Clinical Importance: MAPSE and TAPSE were lower in cats with HCM than in control cats and were lowest in CHF, suggesting that systolic longitudinal dysfunction is present in cats with HCM. MAPSE and TAPSE have potential prognostic significance.

Key words: Echocardiography; Feline; Hypertrophic cardiomyopathy.

Hypertrophic cardiomyopathy (HCM) is the most common heart disease in cats.[1,2] It is characterized by a hypertrophied left ventricle in the absence of other cardiovascular or systemic causes.[3] Recently, it has been reported that increased right ventricular wall thickness is common in cats with HCM and related to the severity of left ventricular hypertrophy.[4] Cats with HCM can have variable life expectancy; several clinical and echocardiographic prognostic factors including left atrial (LA) size and function, extreme left ventricular hypertrophy, measures of left ventricular systolic and diastolic function, presence of congestive heart failure, and aortic thromboembolism have been associated with decreased survival in cats with HCM.[5–9]

Abbreviations:

LA/Ao	left atrial-to-aortic root ratio
LAD	left atrial diameter in long axis
LAFS	left atrial fractional shortening
LVFS	left ventricular fractional shortening
MAPSE	mitral annular plane systolic excursion
S′ FW	tissue Doppler-derived S′ wave at the left ventricular free wall
S′ IVS	tissue Doppler-derived S′ wave at the interventricular septum
TAPSE	tricuspid annular plane systolic excursion

Mitral annular plane systolic excursion (MAPSE) and the right-sided counterpart tricuspid annular plane systolic excursion (TAPSE) are M-mode-derived indices of systolic longitudinal displacement of the atrioventricular annular plane.[10,11] MAPSE and TAPSE can therefore be considered as markers of left ventricular (LV)[10,12] and right ventricular (RV)[11,13] long-axis function, respectively. It is recognized, however, that left-sided heart disease can also influence TAPSE.[14,15]

Currently, there are no published reference values for MAPSE and TAPSE in cats and no information on their potential diagnostic and prognostic utility in HCM.

Study Aims

1 To provide preliminary reference intervals for MAPSE and TAPSE in healthy cats.
2 To determine whether cats with HCM have lower values of MAPSE and TAPSE compared to control cats and whether lower MAPSE and TAPSE are associated with the presence of CHF.

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3 To investigate whether lower values of MAPSE or TAPSE have prognostic value in cats with HCM.

Materials and Methods

Retrospective study. The electronic patient record of the Queen Mother Hospital for Animals (QMHA) was reviewed for cats diagnosed with HCM between April 2013 and September 2015. The control group comprised healthy cats undergoing cardiac assessment as part of blood donor program.

To be included in the study, a complete case record (owner data, cat/donor signalment and history, complete physical examination, and current medications) and a complete echocardiographic examination were required. An additional inclusion criterion was a left apical 4-chamber cineloop of adequate quality to measure MAPSE and TAPSE.

Exclusion criteria included cats diagnosed with other conditions that could affect LV wall thickness such as hyperthyroidism, systemic hypertension, acromegaly, cardiomyopathies other than HCM, congenital heart disease, or neoplastic disease, or those with incomplete case record or echocardiographic examination.

A complete standard echocardiographic examination including M-mode, B-mode, and Doppler echocardiography was performed in all cats in accordance with published human and veterinary guidelines for human and veterinary medicine.[11,16]

Cats were diagnosed with HCM when end-diastolic left ventricular wall thickness measured in B-mode was equal to or greater than 6 mm. In addition, LA size and function were assessed by measuring left atrium-to-aorta ratio (LA/Ao) at the onset of QRS,[8,17] left atrial diameter in long axis (LAD)[8,17] measured at end systole and left atrial fractional shortening (LAFS).[8] Left ventricular systolic function was assessed by left ventricular fractional shortening (LVFS) on M-mode.[8] Where available, the S′ wave of the interventricular septum (S′ IVS) and left ventricular free wall (S′ FW) were measured from mitral annular septal and free wall tissue Doppler imaging (TDI), respectively.[11,12,18]

Cats with HCM were classified as asymptomatic if they were not receiving any cardiac medication and had no signs or history of increased respiratory rate, dyspnea, syncope, or systemic thromboembolism.

To be included in the CHF group, cats had to have increased respiratory rate, abnormal thoracic auscultation, and evidence of pulmonary edema or pleural effusion by imaging (either thoracic ultrasound or thoracic radiography) at the time of presentation at QMHA. The full echocardiographic examination occurred no later than 24 hours after admission following stabilization where necessary. All echocardiographic examinations were performed by a board-certified veterinary cardiologist or a resident under the supervision of a specialist cardiologist.

Off-line measurements of MAPSE and TAPSE were performed by anatomic M-mode[a] from the left apical 4-chamber view as described in human guidelines and dogs.[10–12,19,20] Briefly, the anatomic M-mode cursor was aligned parallel to the interventricular septum (for MAPSE IVS), free wall (for MAPSE FW), or the right ventricular free wall (for TAPSE), and an M-mode tracing was obtained. Both MAPSE and TAPSE were measured in mm with electronic calipers between the most basilar position of the tricuspid annulus in end diastole and its most apical displacement at end systole by the leading edge method (Fig 1). All TAPSE and MAPSE measurements were performed by a single observer (IS). Five consecutive measurements were performed and the results were averaged. Intra- and interobserver variability for the acquisition of the anatomic M-mode image and subsequent measurement was assessed in a randomly selected 10% of the population. Measurements for intraobserver repeatability were performed by a single observer (IS) on 2 occasions 1 week apart from each other. Measurements for interobserver repeatability were performed independently by 2 observers (IS and JRP).

Survival information for the cats diagnosed with HCM was obtained by reviewing the electronic clinical archive and by contacting referring veterinarians. All-cause mortality was the end-point in the survival analysis. Cats still alive were censored in the statistical analysis; subjects lost to follow up were included in the survival analysis up until the last time point at which they were known to be alive and then were thereafter censored in the analysis.

Statistical Analysis

Statistical analysis was performed by a commercially available statistical software[b] , and in all cases, statistical significance was set at $P < .05$. The Shapiro-Wilk test was used to verify normal

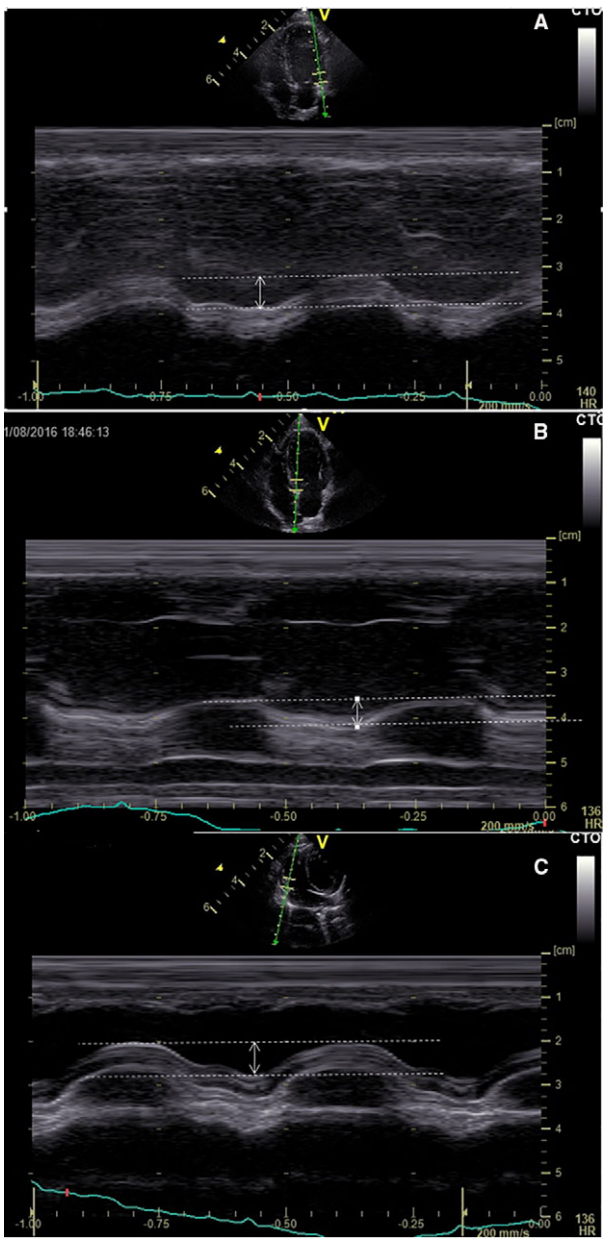

Fig 1. Technique to acquire and measure MAPSE and TAPSE by M-mode from the 4-chamber left apical view. See text for details.

distribution of variables. Non-normally distributed data are reported as median (interquartiles range, IQR1-3, 25th percentile to 75th percentile).

Mann-Whitney *U* or Kruskal-Wallis test was used to compare ordinal and continuous, non-normally distributed data as appropriate. Posthoc comparisons were performed by Dunn's method.

For the repeatability study, intra- and interobserver coefficients of variation (CV) were calculated and Bland-Altman plots were obtained.

Reference intervals were calculated based on 90% confidence intervals, as recommended for normally distributed populations with 20–40 individuals.[21]

Survival was calculated as the days between diagnosis and death or last visit. The Kaplan-Meier method was used to estimate survival function and plot time to event curves in the different groups. Continuous variables were explored by division into groups based on tertiles. A log-rank test with right censoring was used to determine whether a significant difference existed among groups.

Results

From April 2013 to September 2015, 100 cats were diagnosed with left ventricular hypertrophy. After exclusion for concurrent systemic disease (n = 22), lack of a suitable 4-chamber apical cineloop (n = 8) or both (n = 6), 64 cats with HCM were included in the study. Of these 64 cats, 45 were asymptomatic and 19 had CHF. The control group comprised 27 healthy blood donor cats.

The median age of the population was 5.6 (3.8–7.0) years, and the median body weight was 4.6 (4.2–5.0) kg. There were 56 males and 35 females. The majority of cats were domestic shorthairs (n = 61), followed by Bengals (n = 6), Persians (n = 6), and Domestic Long Hairs (n = 5). Other breeds included were British Short Hairs and Ragdolls (n = 3), Maine Coons, Scottish Fold and Birman (n = 2), Selkirk Rex (n = 1).

Reference intervals were generated for healthy control cats (Table 1).

There was no significant difference between controls and cats with HCM with regard to age ($P = .15$), sex ($P = .45$), body weight ($P = .46$), or LVFS ($P = .45$). Cats with HCM had larger LAD ($P < .001$) and LA/Ao ($P < .001$) than control cats. Cats with HCM had lower LAFS ($P < .001$), TAPSE ($P < .001$), MAPSE IVS ($P < .001$), MAPSE FW ($P < .001$), S′ IVS ($P = .037$), and S′ FW ($P < .001$) than controls (Table 2).

When comparing control cats, asymptomatic cats with HCM, and cats with HCM and CHF, cats with HCM and CHF had significantly lower MAPSE IVS, MAPSE FW, and TAPSE than asymptomatic cats with HCM ($P < .001$, $P < .001$, and $P < .001$, respectively) and significantly lower MAPSE IVS, MAPSE FW, and TAPSE ($P < .001$, $P < .001$, and $P < .001$, respectively) than healthy control cats. Asymptomatic cats with HCM had a significantly lower MAPSE IVS ($P < .001$), MAPSE FW ($P < .001$), and TAPSE ($P < .001$) compared to healthy control cats (Figs 2-4, Table 2).

Table 1. Distribution of data for MAPSE and TAPSE in 27 healthy cats.

	MAPSE FW	MAPSE IVS	TAPSE
Mean (mm)	5.89	5.22	9.02
Standard deviation	0.65	0.59	2.18
Reference interval (90% confidence interval)	5.67–6.12	5.02–5.43	8.27–9.77
Minimum	4.90	4.20	5.20
Maximum	7.30	6.30	13.40

At the end of the study period, 38 of the 64 cats with HCM were still alive, 6 were lost to follow up, and 20 had died. At the univariable level, increased LAD and LA/Ao and decreased LAFS, MAPSE IVS, MAPSE FW, and TAPSE (Table 3, Figs 4-7) were all associated with reduced survival times.

Intra- and interobserver coefficient of variation showed good repeatability for acquisition and measurement of MAPSE and TAPSE (Table 4) with minimal bias (Figs 8-10).

Discussion

The results of our study indicated that cats with HCM have lower MAPSE and TAPSE values as compared to healthy control cats. Furthermore, cats with CHF showed the lowest values of MAPSE and TAPSE. Although the number of cats in the analysis was small, lower MAPSE and TAPSE were also associated with a decreased survival time for all-cause mortality, suggesting potential prognostic value. Further studies with a greater number of cats should enable a greater appreciation of the prognostic utility of MAPSE and TAPSE for both cardiac and all-cause mortality. The intra- and interobserver CV as well as the Bland-Altman limits of agreement indicated that the technique is easily achievable and repeatable among different observers.

Shortening of the left ventricle in the longitudinal axis is one of the major components of cardiac contraction as the heart base displaces toward the apex. MAPSE and TAPSE measure the longitudinal displacement of the annular plane during the cardiac cycle and can therefore be considered as markers of systolic long-axis function. It has been estimated that the contribution of longitudinal contraction as assessed by atrioventricular plane displacement is responsible for up to 60% of the total cardiac stroke volume in healthy human adults.[22] A decrease in longitudinal function has been identified by speckle-tracking echocardiography in the early stages of HCM in people.[23,24] Furthermore, MAPSE measured by MRI is decreased in people with obstructive and nonobstructive HCM and correlates with the presence of fibrosis as assessed by late gadolinium enhancement.[25]

Similarly, the findings of our study indicate that cats with HCM have lower MAPSE compared to normal cats, confirming reduced systolic longitudinal function even in those cats not showing clinical signs. This parallels the findings in human medicine.[23,24]

Left ventricular functional abnormalities might be expected in cats with HCM, but our study showed that RV longitudinal displacement is also reduced in cats

Table 2. Population characteristics and echocardiographic findings in the 91 cats enrolled in the study. Data are presented as median (IQR1-3). The Greek letter indicates a statistically significant difference within the groups based on posthoc analysis. α = normal vs HCM asymptomatic; β = normal vs HCM with CHF; γ = HCM asymptomatic vs HCM with CHF. Bold values indicate statistically significant results.

	Normal	HCM	*P* value (Normal vs HCM)	Asymptomatic HCM	HCM with CHF	Overall *P* value (normal vs asymptomatic HCM vs HCM with CHF)
Age (years)	4.8 (2–7.9)	5.2 (3–8.9)	*P* = .15	5.8 (3.7–8.2)	6.0 (3.3–8.8)	*P* = .30
Sex	15♂ 12♀	41♂ 23♀	*P* = .45	30♂ 15♀	11♂ 8♀	*P* = .55
Breed	18 DSH, 2 DLH, 2 Maine Coon, 1 each Ragdoll, Bengal, Persian, BSH, Selkirk Rex	43 DSH, 5 Persian, 5 Bengal, 3 DLH, 2 Birman, 2 Ragdoll, 2 BSH, 2 Scottish fold		31 DSH, 4 Bengal, 3 DLH, 3 Persian, 1 each Ragdoll, Birman, BSH, Scottish fold	12 DSH, 2 Persian, 1 each Bengal, Birman, Ragdoll, Scottish Fold and BSH	
Weight (kg)	4.3 (3.7–5.2)	4.6 (3.9–5.2)	*P* = .46	4.7 (4.0–5.3)	4.2 (3.7–5.1)	*P* = .49
Heart rate (bpm)	176 (161–211)	184 (158–200)	*P* = .79	175 (158–193)	200 (187–211)	*P* = .09
LAD (mm)	$14.3^{\alpha\beta}$ (13.0–15.3)	16.5 (14.4–19.5)	***P* < .001**	$16.0^{\alpha\gamma}$ (14.1–17.9)	$19.9^{\beta\gamma}$ (16.2–22.6)	***P* < .001**
LA/Ao ratio	$1.27^{\alpha\beta}$ (1.12–1.36)	1.51 (1.35–2.03)	***P* < .001**	$1.39^{\alpha\gamma}$ (1.28–1.60)	$2.10^{\beta\gamma}$ (1.80–2.39)	***P* < .001**
LAFS (%)	33.4^{β} (28.9–36.9)	23.9 (16.8–30.5)	***P* < .001**	26.6 (22.4–32.7)	13.3^{β} (7.6–20.3)	***P* < .001**
LVFS (%)	49.5 (45.1–53.5)	47.5 (41.2–59.2)	*P* = .45	57.0 (43.1–61.9)	44.8 (38.3–56.7)	*P* = .07
TAPSE (mm)	$8.6^{\alpha\beta}$ (7.4–10.2)	6.7 (4.7–7.6)	***P* < .001**	7.2^{α} (6.3–8.2)	$4.6^{\beta\gamma}$ (4.1–5.4)	***P* < .001**
MAPSE IVS (mm)	$5.2^{\alpha\beta}$ (4.6-5.6)	4.3 (2.9-5.0)	***P* < .001**	$4.7^{\alpha\gamma}$ (4.1–5.2)	2.6^{β} (2.5–3.2)	***P* < .001**
MAPSE FW (mm)	$5.9^{\alpha\beta}$ (5.3-6.2)	4.6 (3.0-4.9)	***P* < .001**	$4.7^{\alpha\gamma}$ (4.1–5.1)	$2.8^{\beta\gamma}$ (2.4–3.2)	***P* < .001**
S′ IVS (cm/s)	9.0^{β} (8.0–10.1)	8.1 (6.1-10.0)	*P* = .04	8.2^{γ} (7.1–10.2)	$6.0^{\beta\gamma}$ (5.0–6.3)	***P* < .001**
S′ FW (cm/s)	$8.5^{\alpha\beta}$ (7.4–10.6)	5.2 (4.4–7.1)	***P* < .001**	$6.2^{\alpha\gamma}$ (5.0–7.6)	$4.4^{\beta\gamma}$ (4.0–5.0)	***P* < .001**

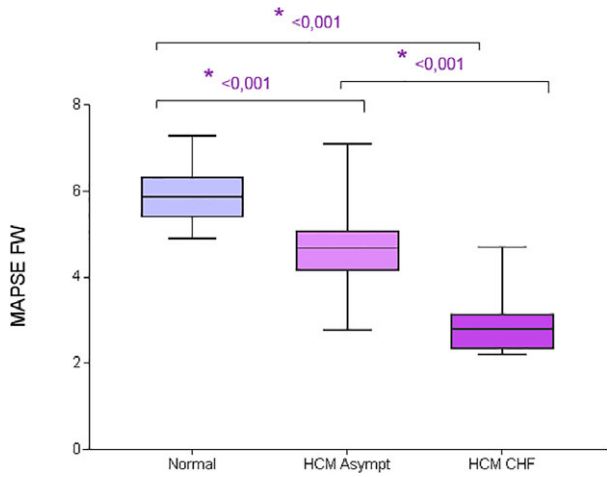

Fig 2. Box and whiskers plot for MAPSE FW in control cats, asymptomatic cats with HCM, and cats with HCM and CHF.

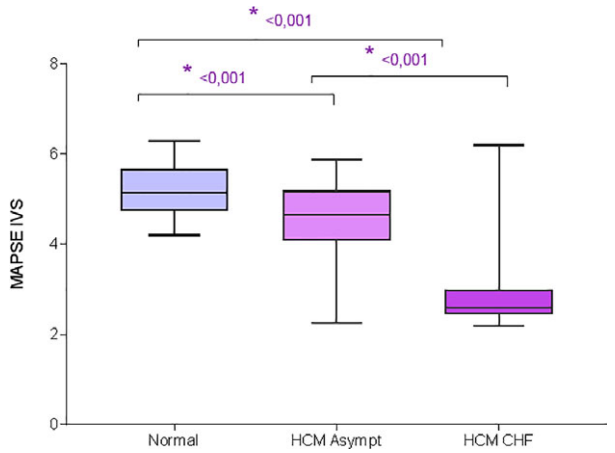

Fig 3. Box and whiskers plot for MAPSE IVS in control cats, asymptomatic cats with HCM, and cats with HCM and CHF.

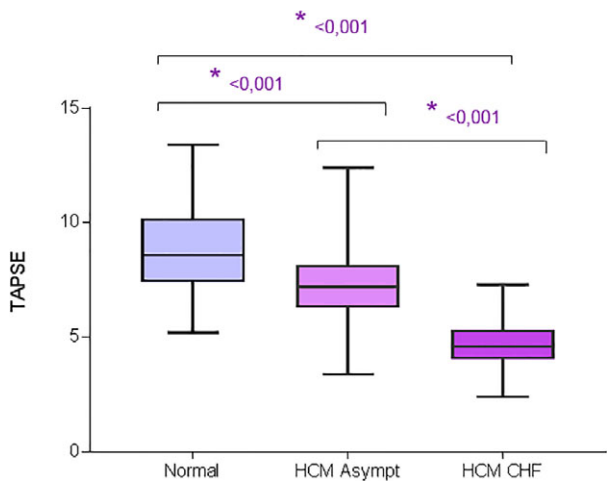

Fig 4. Box and whiskers plot for TAPSE in control cats, asymptomatic cats with HCM, and cats with HCM and CHF.

Table 3. Univariable survival analysis. Median survival time (MST) and ranges are displayed. Bold values indicate statistically significant results.

Variables	Tertiles	Median survival time	*P* value
LAD	<15.1 mm	>2884 day (0–2884 day)	**<.001**
	15.1–18.8 mm	>1748 day (0–1748 day)	
	>18.8 mm	257 day (0–1865 day)	
LA/Ao	<1.4 mm	>1748 day (0–1748 day)	**<.001**
	1.4–1.9 mm	>2884 day (0–2884 day)	
	>1.9 mm	500 day (0–1865 day)	
LAFS	<20.2%	160 day (0–500 day)	**<.001**
	20.2–27.3%	208 day (12–1014 day)	
	>27.3%	>2884 day (0–2884 day)	
LVFS	<44.0%	500 day (0–1086 day)	.093
	44–58.4%	>2884 day (0–2884 day)	
	>58.4%	1014 day (0–1139 day)	
MAPSE FW	<3.3 mm	255 day (0–1016 day)	**<.001**
	3.3–4.8 mm	>1748 day (0–1748 day)	
	>4.8 mm	>2884 day (0–2884 day)	
MAPSE IVS	<3.3 mm	580 day (0–1016 day)	**.002**
	3.3–4.7 mm	>1865 day (0–1865 day)	
	>4.7 mm	>2884 day (0–2884 day)	
TAPSE	<5.3 mm	500 day (0–1016 day)	**<.001**
	5.3–7.2	>1086 day (0–1086 day)	
	>7.2	>2884 day (0–2884 day)	
S′ FW	<4.6	1014 day (0–1865 day)	.167
	4.6–6.5	>1139 day (0–1139 day)	
	>6.5	>2884 day (0–2884 day)	
S′ IVS	<6.0	>1865 day (12–1865 day)	.110
	6.0–9.0	>1748 day (0–1748 day)	
	>9.0	>2884 day (0–2884 day)	

with HCM. This parallels findings in people with HCM, where a decrease in TAPSE has been documented.[15] It remains unclear whether the decrease in TAPSE can be purely attributed to concomitant right ventricular cardiomyopathy, which has been identified in one-third of human patients and about half of cats with HCM.[4,26] Alternatively left-sided heart disease may provoke right ventricular dysfunction through a number of pathophysiological mechanisms including the development of pulmonary hypertension,[27,28] reduction in right ventricular compliance due to ventricular interdependence,[15,28] or cause detrimental alteration in right ventricular coronary perfusion pressure. One or more of these mechanisms may explain the reduction in TAPSE identified in this study.[12,15,27,28]

In this report, cats with CHF had the lowest values for MAPSE and TAPSE, which probably reflects disease progression and worsening systolic dysfunction. A similar finding was reported for LVFS in cats with more advanced disease.[8,9]

Furthermore, cats in the lowest tertile for each of MAPSE IVS, MAPSE FW, and TAPSE were more likely to reach the final end-point of all-cause mortality, suggesting that these echocardiographic parameters have potential prognostic value. Left atrial size and function was also shown to be of prognostic importance in our population, as identified in previous studies.[6–9]

Because of the low number of events, it was not possible to assess the prognostic utility of these variables for cardiac mortality and there were too few events to

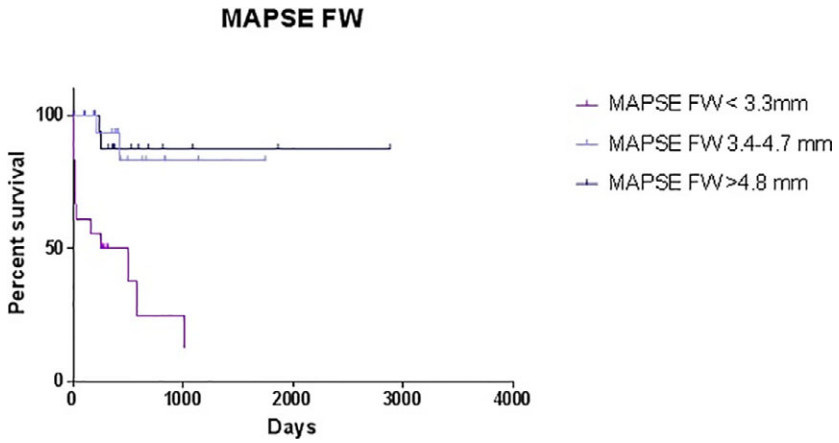

Fig 5. Kaplan-Meier survival curve for MAPSE FW. Log-rank test, $P < .001$. Median survival time for MAPSE FW <3.3 mm is 255 days (0–1016 day); for MAPSE FW 3.4–4.7 mm, median survival time is >1748 days (0–1748 day); for MAPSE FW >4.8 mm, median survival time is >2884 day (0–2884 day).

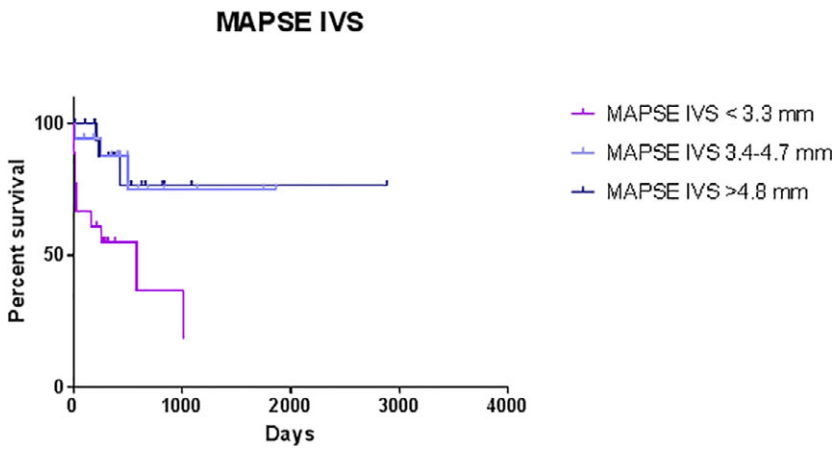

Fig 6. Kaplan-Meier survival curve for MAPSE IVS. Log-rank test, $P = .002$. Median survival time for MAPSE IVS <3.3 mm is 580 days (0–1016 day); for MAPSE IVS 3.4–4.7 mm, median survival time is >1865 days (0–1865 day); and for MAPSE >4.8 mm, median survival time is >2884 days (0–2884 day).

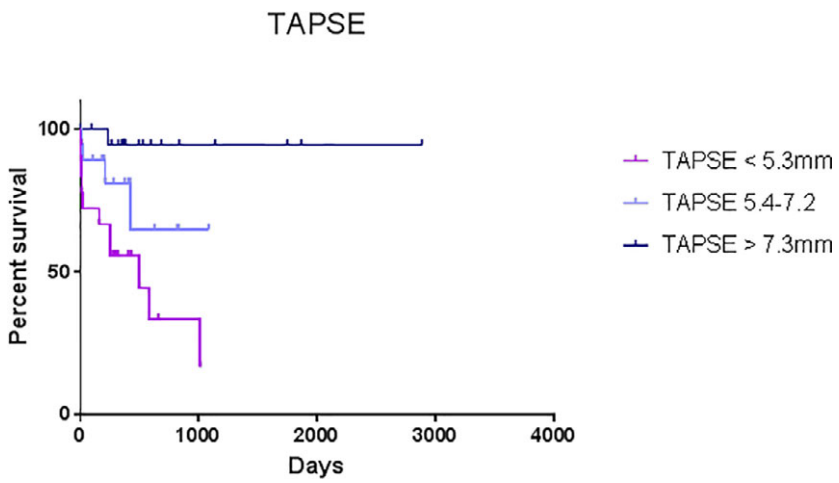

Fig 7. Kaplan-Meier survival curve. Log-rank test, P value <.001. Median survival time for TAPSE I < 5.3 mm is 500 days (0–1016 day); for TAPSE 5.4–7.2 mm, median survival time is >1086 days (0–1086 day); and for TAPSE >7.3 mm, median survival time is >2884 days (0–2884 day).

Table 4. Intra- and interobserver CV for MAPSE and TAPSE.

CV	Intraobserver (1) (%)	Interobserver CV (%)
MAPSE FW	2.0	8.0
MAPSE IVS	1.6	8.0
TAPSE	1.5	5.0

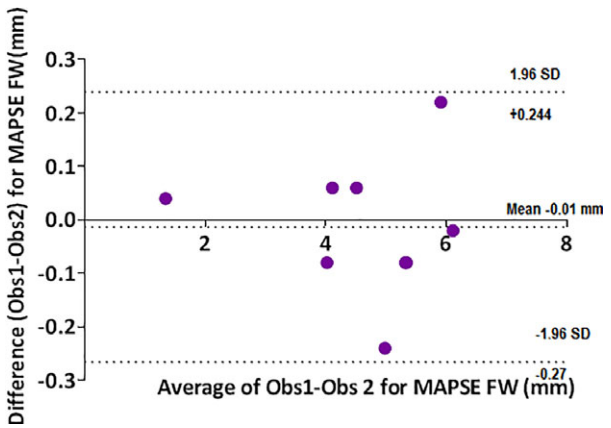

Fig 8. Bland-Altman Plot for MAPSE FW. Mean bias −0.01 (−0.27 to 0.244) mm.

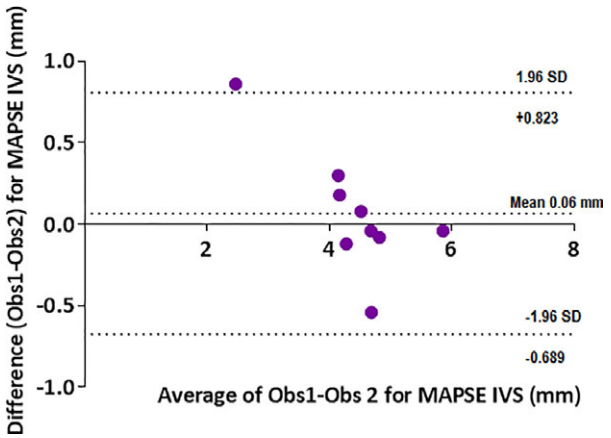

Fig 9. Bland-Altman Plot for MAPSE IVS. Mean bias 0.06 (−0.69 to 0.82) mm.

perform multivariable analysis for a final model of survival. That said, these preliminary findings are encouraging and in agreement with a recent study which showed that right ventricular dysfunction based on TAPSE was independently associated with an increased likelihood of death or transplantation[15] and therefore warrant further study with a greater number of cats.

Both MAPSE and TAPSE are techniques that do not require special expertise or advanced echocardiographic imaging techniques and are easy to obtain and measure after minimal training.[10] These techniques have the added advantage that there is no major negative effect

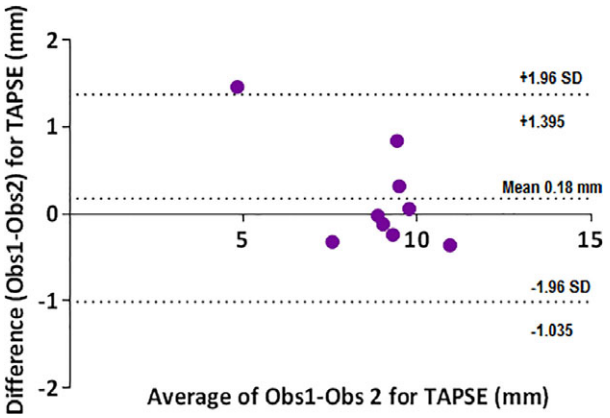

Fig 10. Bland-Altman for TAPSE. Mean bias 0.18 (−1.04 to 1.40) mm.

of apical fore-shortening as the measurements are taken at the AV plane. There are more advanced techniques to assess longitudinal function such as tissue Doppler imaging (TDI) or speckle-tracking echocardiography (STE), but they require advanced and more expensive software, generally low heart rates, high frame rates, and adequate image quality. They are also associated with a steeper learning curve.[10]

To the authors' knowledge, no reference intervals of MAPSE and TAPSE have been published for cats. In dogs, a curvilinear relationship was found between TAPSE and weight, which became linear once weight was normalized to a scale of 1/3.[19] Cats may vary in weight but this is generally less pronounced compared to dogs, where body weight has a substantial breed-dependent variation; however, as standard echocardiographic parameters vary with body weight,[29] the authors recommend that the preliminary MAPSE and TAPSE values provided in this study are applicable in cats with a body weight between 3.7 and 5.2 kg. Further studies are needed to establish the extent of MAPSE and TAPSE variation based on weight- and breed-related differences in cats.

The present study has some limitations. First of all, being a retrospective study, it was not possible to measure TAPSE from a left apical view optimized for the right ventricle in all cases. As with all techniques needing a good alignment, MAPSE and TAPSE measurement may be hindered by a degree of malalignment; however, we were able to minimize this by the use of anatomic M-mode which enabled us to achieve acceptable intra- and interobserver CV. However, further validation of the day-to-day variability in these longitudinal function indices is justified to further assess their accuracy and reproducibility in prospective studies. This study did not attempt to establish correlations among MAPSE, TAPSE, and other echocardiographic measures of disease severity such as atrial and ventricular size and function or invasive catheterization data, for instance, to determine presence and severity of pulmonary hypertension. Interestingly, it has been shown in human patients with HCM that right ventricular

dysfunction measured by TAPSE was independently associated with the degree of left ventricular diastolic and systolic dysfunction and pulmonary hypertension.[15] Furthermore, we did not evaluate the influence of medications such as furosemide on echocardiographic parameters, which through reduction in preload may influence longitudinal function. Due to the low number of events, we were unable to perform a multivariable survival analysis and further studies are needed to confirm our preliminary survival findings and to assess whether MAPSE and TAPSE have prognostic value for cardiac mortality.

The authors tried to exclude all possible secondary causes of left ventricular hypertrophy based on the available data for each case. However due to the retrospective nature of the study and the challenges associated with a final confirmation of myocarditis, we cannot completely rule out the possibility that cats with rare causes of LVH such as transient myocarditis were included in the study. Finally, due to the retrospective nature of the study, it was not possible to blind the investigator performing echocardiographic measurements to the clinical diagnosis of the cats, which may have introduced bias into our results.

In conclusion, cats with HCM had lower MAPSE IVS, MAPSE FW, and TAPSE, with the lowest values in cats with CHF. Furthermore, our preliminary data indicated that cats with MAPSE below 3.3 mm and TAPSE below 5.3 mm had reduced survival times. Importantly, the technique was found to be feasible in the majority of cats with acceptable intra- and interobserver CV.

Footnotes

[a] Vivid 7 with Echo Pac off-line measurement software, GE systems, Hatfield, UK

[b] IBM® SPSS® Statistics version 22, IBM (UK) Ltd, Portsmouth, UK

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Conflict of Interest Declaration: The authors declare no conflict of interest.

Off-label Antimicrobial Declaration: The authors declare no off-label use of antimicrobials.

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