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Impaired left ventricular systolic function assessed by endocardial global longitudinal strain imaging in cats with restrictive cardiomyopathy

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KEYWORDS
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Abstract *Introduction/Objectives:* Restrictive cardiomyopathy (RCM), the second most common cardiomyopathy in cats, is known to induce primary diastolic dysfunction. Little is known about systolic function in cats with RCM. The aim of this study was to evaluate systolic function using two-dimensional speckle-tracking echocardiography—derived endocardial global longitudinal strain (GLS) in a population of cats with RCM.
Animals, Materials and Methods: Twenty-five adult cats diagnosed with RCM as well as 25 healthy control cats were included in the present study. Left apical two-, three-, and four-chamber views were obtained retrospectively for endocardial GLS analysis derived by two-dimensional speckle tracking. Comparison of cats with RCM with a matched control group was performed.
Results: Cats with RCM had significantly larger left ventricular internal diameters in both, systole ($P < 0.0001$) and diastole ($P = 0.0015$), than controls. In systole, cats with RCM had values of 11.05 mm $\pm$ 2.24, in contrast to those of 8.48 mm $\pm$ 1.35 in healthy controls. In diastole, these values were 16.10 mm (range: 10.50—20.60 mm) in cats with RCM, higher than 14.90 mm (range: 10.00—17.50 mm) in the control group. Global longitudinal strain values were significantly lower in cats diagnosed with RCM than in control cats ($P < 0.0001$), with a mean value of $-17.68\% \pm 4.78$ vs. $-28.35\% \pm 3.72$, respectively.

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Study Limitations: Limitations mainly comprised the retrospective character of the study, leading to lack of treatment standardization and histopathology, as well as a limited population of felines.
Conclusions: Endocardial GLS is reduced in cats with RCM, indicating that cats with RCM not only have a diastolic but also systolic dysfunction.

Introduction

Restrictive cardiomyopathy (RCM) is recognized as the second most prevalent cardiomyopathy in cats [1].

Fibrosis is a hallmark of RCM and manifests in two primary forms: myocardial and endomyocardial. The former is characterized by diffuse, patchy, white-gray fibrotic areas throughout the myocardium [2,3]. The latter additionally affects the endocardium, with distinct intracavitary trabeculation and a net-like pattern of fibrotic tissue spanning the cavities. Functionally, this can lead to ventricular stenosis and intracavitary flow obstruction. According to the American College of Veterinary Internal Medicine consensus statement guidelines for the classification, diagnosis, and management of cardiomyopathies in cats, the endomyocardial form of RCM is defined by a prominent endocardial scar usually bridging the interventricular septum and left ventricular (LV) free wall and may cause fixed, mid-LV obstruction and often apical LV thinning or aneurysm with left atrial or bi-atrial enlargement. In comparison, the myocardial form comprises normal LV dimensions with left-atrial or bi-atrial enlargement [4]. Many affected cats with RCM do not present with a heart murmur, often leading to a delayed diagnosis in the clinical stage. The prognosis for cats presenting with respiratory distress is guarded, with a reported median survival time of 64 days [5]. Among those experiencing syncope or feline arterial thromboembolism, survival is reduced to a median of 52 days [3]. In contrast, cats without clinical respiratory symptoms show a median survival time of 466 days [5].

The heterogenic nature of RCM presents challenges in defining a clear etiology. Hypereosinophilia and inflammatory heart disease have been suggested as contributing factors to endomyocardial fibrosis, as noted in human medicine [6—9]. Studies indicate concomitant systemic diseases in over 50% of cats with RCM phenotype, of which 35% were of infectious origin [10]. A genetic predisposition remains largely unexplored in feline patients, while such factors have been documented in human cases [11,12].

Replacement of functional myocardial with fibrotic tissue not only leads to anticipated diastolic dysfunction with restricted ventricular filling [13]; it consequently results in left-atrial or bi-atrial dilation without ventricular wall thickening. Myocardial fibrosis, essentially replacement fibrosis, may also impact cardiac systolic function. To the authors' knowledge, only one study has assessed systolic function in feline RCM [14].

Understanding systolic function in RCM may have important implications for identifying therapeutic options and improving clinical outcomes in the future. The aim of this study was to evaluate LV systolic function in cats with RCM using endocardial global longitudinal strain (GLS) and to compare these findings with those of a matched healthy population. We hypothesized that cats with RCM exhibit impaired systolic function, as reflected by reduced GLS.

Animals, materials, and methods

The present study was designed in a retrospective manner.

Client-owned cats presented with respiratory distress or heart murmurs were examined at the Small Animal Clinic of the Ludwig-Maximilians University Munich between 2018 and 2024.

Cats were included if a diagnosis of RCM, either the myocardial or the endomyocardial form, was confirmed via echocardiography. Bi-atrial or left atrial dilation was required and defined by an aortic-to-left atrium ratio greater than 1.6 in the right parasternal short-axis view or a maximum left atrial diameter greater than 16 mm in the right parasternal long-axis view [15]. Right atrial assessment was conducted qualitatively and quantitatively [16,17]. Left ventricular and interventricular end-diastolic wall thicknesses were supposed to be within established reference ranges. Cats exhibiting evidence of LV concentric hypertrophy were excluded from the study. This condition was defined by an interventricular septal

diameter or LV posterior wall diameter in diastole exceeding 6 mm or established allometric scaling reference values [18]. Additional inclusion criteria were evidence of diastolic dysfunction, defined by mitral inflow (E-wave-to-A-wave ratio >2.0) given E-wave and A-wave were not fused, shortened isovolumetric relaxation time (isovolumetric relaxation time <37 ms), and pulsed-wave tissue velocity imaging (E' <6 m/s; E/E' >12), as recommended in the study by Schober and Chetboul [13]. In the presence of fused E-wave and A-wave, diagnosis was based on two-dimensional criteria, tissue Doppler, and isovolumetric relaxation times. It was further supported by fused E-velocity and the ratio of fused E-wave and A-wave to fused E′-velocity and A′-velocity.

Congestive heart failure was confirmed by radiographs, ultrasound, or both. Suspicion of constrictive pericarditis such as marked cyclic variation of the mitral- and/or tricuspid inflow led to exclusion from the study. The use of antithrombotic agents, including clopidogrel and/or rivaroxaban, diuretics such as furosemide or torsemide was permitted within the RCM group. Additionally, antiarrhythmic medications, such as atenolol, were allowed if deemed necessary for the management of relevant arrhythmias. Cats receiving positive inotropic medication, essentially pimobendan, were not necessarily excluded if it was inevitable for the management of their clinical condition. Other medications needed to treat relevant comorbidities, such as thiamazole, did not lead to exclusion. Cats with arrhythmias were excluded, with the exception of cats with atrial fibrillation. Two cats with atrial fibrillation were included as ventricular response rates were within a controlled range according to the clinical conditions.

A healthy control group was matched for sex and age and included cats presented for screening or breeding examinations. Control cats were classified as healthy based on medical records, a comprehensive clinical examination, and a complete echocardiographic assessment, including simultaneous electrocardiographic recording in both right and left lateral recumbent positions without sedation. Control cats were excluded if they displayed any cardiac rhythm other than sinus rhythm or were receiving cardiovascular medications. All healthy cats had a physiological body condition score between 4 and 6 out of 9. Additional exclusion criteria included end-diastolic wall diameter, LV systolic or diastolic chamber diameters outside established reference intervals [18], or the presence of diastolic dysfunction, as determined by mitral inflow profiles, tissue velocity imaging, and isovolumetric relaxation time [13]. Control cats were also screened for LV outflow tract obstruction and excluded if present. Trace valvular regurgitation detected by color flow Doppler, or dynamic right ventricular outflow tract obstruction, was acceptable if there was no structural indication for valvular dysplasia or degenerative process. Laboratory tests or blood pressure measurements were performed only when ethically indicated, minimizing additional stress to the patients and conducted at the owner's discretion.

Echocardiographic examination

All transthoracic echocardiographic studies have been performed by a board-certified cardiologist or a cardiology resident under direct supervision.

An ultrasound unit[c] with a 12-MHz transducer was used in all studies. Simultaneous electrocardiogram was recorded, and the heart rate was monitored by this means. Cats in acute congestive heart failure received intravenous loop diuretics (furosemide) and oxygen prior to the complete echocardiographic examination for stabilization and risk reduction. Patients with chronic congestive heart failure received oral loop diuretics and antithrombotics and cats with acute feline arterial thromboembolism received analgesic medication with methadone at the time of echocardiographic examination. In four cats, pimobendan was introduced by another veterinarian prior to the echocardiographic examination.

Routine echocardiographic measurements [4,19], including two-dimensional interventricular septal wall diameter, LV internal diameter, and LV posterior wall diameter both in systole and diastole, were obtained in each patient in the right parasternal long-axis view and compared to established reference values [18]. Left ventricular wall thickness and interventricular septal thickness were measured using a leading edge-to-leading edge approach comprising the average of at least three measurements. As no concentric hypertrophy was supposed to be present, the measurements were conducted midventricular and the direct insertion area of false tendons was avoided. Aiming at improved repeatability, initial measurements were repeated offline by the investigator of this study as echocardiographic examiners differed given the retrospective nature of the study. The diameters of the aortic root and left atrium were measured two frames after the T-

[c] EPIQ 7, Philips GmbH Market DACH, Hamburg, Germany.

wave in a right parasternal short-axis view at the level of the heart base, and the left atrium-to-aortic ratio was calculated. Right atrial size was evaluated qualitatively and quantitatively on a right parasternal long-axis view optimized for visualization of the atria. The maximum right atrial diameter was measured at end-systole from the midpoint of the interatrial septum to the right atrial lateral wall in a cranial-caudal plane and parallel to the tricuspid valve annulus. Assessment by standard spectral, color flow Doppler, and tissue velocity imaging was performed, as previously described [13,19]. Diastolic function was assessed by early diastolic filling velocity, atrial kick velocity, and the ratio of the latter, provided they were not fused. For the evaluation of diastolic function, tissue velocity imaging was performed additionally on the septal and lateral walls at the level of the mitral annulus. Isovolumetric relaxation time measured by pulsed-wave Doppler with the gate placed between the aorta and the septal hinge point of the mitral valve was included in the diastolic analysis.

Two-dimensional endocardial GLS measurements were obtained from a combined left apical two-, three-, and four-chamber view. Cats were excluded if one of the views was missing or the image quality was inadequate. Endocardial GLS analysis based on two-dimensional speckle-tracking echocardiography was performed offline by a single investigator using TomTec ARENA software [d], who was not blinded to the clinical status of the cats. For that purpose, cardiac performance analysis was used including the analysis of three echocardiographic views, as described previously [20].

Tracking was conducted using the 3-point method as follows: One point each was placed on the endocardium at the level of the lateral hinge point of the mitral valve, at the level of the septal hinge point of the mitral valve, and at the LV apex.

Electrocardiogram tracings were reviewed, and time points of respective R-waves, ventricular end-systole, and ventricular end-diastole were adjusted manually if deemed necessary. Analysis was performed automatically by the software. Manual adjustment of the endocardial border was performed only when necessary to ensure accurate tracking.

The LV free wall and interventricular septum were divided by the software into three parts: basal, mid, and apical. Endocardial longitudinal strain values were generated, and a global value was calculated. All segments and all three views were considered. The results were visually inspected using a bull's eye.

Statistical analysis

MedCalc[e] as well as R[f] have been used for statistical analysis. Parameters were tested for normality using the Shapiro-Wilk test, and outlier detection was performed.

For homogeneity of variance, *F*-test was used, assuming a normal distribution. Otherwise, Levene's test was used. As the variances were equal, the one-sample Student's *t*-test was used to compare RCM and control cats. If unequal variances were assumed, Welch's test was used. If the distribution was not normal, a Mann-Whitney *U* test was performed. For the analysis of test performance, receiver operating characteristic curves were established for endocardial GLS values and Youden index was calculated to investigate test performance.

Authors declare no off-label use of antimicrobials. Authors declare Institutional Animal Care and Use Committee (IACUC) or other approval declaration was not needed for this study due to the retrospective study design. Authors declare human ethics approval was not needed for this study.

Results

The study population consisted of 25 adult cats diagnosed with either the myocardial (n = 23) or the endomyocardial (n = 2) form of RCM and 25 healthy control cats.

The RCM cats either were presented because of respiratory distress and/or pulseless paresis of the hind limbs or were referred to the cardiology service because of a heart murmur or arrhythmia.

Of the 25 cats with RCM, 18 were domestic shorthair cats. One cat from each of the following breeds was included: Abyssinian, Burmese, British shorthair, Maine Coon, Selkirk Rex, Sphynx, and Thai cat. Controls included 16 domestic shorthair cats, Norwegian Forest (n = 3), British shorthair (n = 2), Bengal (n = 1), Burmese Mix (n = 1), Maine Coon (n = 1), and a Siamese cat (n = 1).

Nine females and 16 males were included in the RCM group, and 11 females and 14 males were

[d] TOMTEC Imaging Systems GmbH, Unterschleißheim, Germany.

[e] MedCalc Software Ltd., version 19.5.3, Ostend, Belgium.

[f] RStudio, Boston, Massachusetts, USA.

included in the control group. Thirty-three cats were excluded from the study due to poor image quality (n = 16), conflicting echocardiographic results without clear diastolic dysfunction (n = 11), or cardiac comorbidities (n = 6). Cardiac comorbidities included suspicion of myocarditis, atrial standstill, third-degree atrioventricular block, pulmonary hypertension, tricuspid valve dysplasia, and suspected atrial myopathy. The age of the RCM group ranged from 3.36 to 19.65 years (12.68 years ± 4.12), while the control group had a median age of 12.91 years (range: 2.87—19.72 years). The median weight was 4.14 kg (range: 2.50—6.00 kg) for the RCM group and 4.00 kg (range: 2.90—6.73 kg) for the control group. The median recorded heart rate was 184 beats/min (range: 150—221 beats/min) for the RCM cats and 183 beats/min (range: 149—236 beats/min) for the controls. Frame rate had a range of 90—141 Hz in the diseased population and 101—152 Hz in the control group.

Hyperthyroidism was the most common comorbidity and was found in seven cats with RCM. It was medically well controlled in all cats. Other comorbidities included diabetes mellitus (n = 2) and nephropathy (n = 3), including protein-losing nephropathy (n = 1) and chronic kidney disease (n = 2). In line with human studies, the classification of RCM phenotype accommodates infiltrative or systemic associated conditions [21]. Therefore, cats with systemic diseases were not necessarily excluded. Two cats had atrial fibrillation, which was presumed to be secondary to structural heart disease. They were not excluded as the ventricular response rate did not exceed sinus rates seen in cats with congestive heart failure under clinical conditions.

Of the 25 RCM cats, 19 experienced an acute episode of congestive heart failure. One cat was stable under diuretic therapy and had experienced a previous episode of heart failure. Feline arterial thromboembolism affecting both hind limbs was present in three patients, two of whom had concurrent congestive heart failure. The remaining four cats were presented for heart murmur based on auscultation and did not show clinical or radiographic signs of congestive heart failure despite having restrictive diastolic function following RCM. Clinical data are shown in Table 1.

Treatment of cats with acute congestive heart failure included at least one initial bolus of

Table 1 Clinical data of the population of cats with restrictive cardiomyopathy.

	No CHF	Former CHF, stable under diuretics	Pleural effusion	Pericardial effusion	Pulmonary edema	Ascites	FATE
1	x						
2	x						
3	x						
4	x						
5	x						x
6		x					
7			x				
8			x				
9			x				
10			x				
11			x				
12			x				
13			x				
14			x				
15			x		x		
16			x	x			
17			x			x	
18					x		
19					x		
20					x		
21					x		
22					x		
23				x	x		
24			x				x
25					x		x

CHF: congestive heart failure; FATE: feline arterial thromboembolism.

furosemide, which was followed by intravenous constant rate infusion of furosemide at 0.5 mg/kg/h for as long as required for stabilization. Conversion to oral treatment with a loop diuretic — either furosemide or torsemide — was conducted as soon as possible according to the cats' respiration rate with following titration of the dosage according to the cats' clinical progression and the assessment of the cardiologist. Anticoagulant therapy with clopidogrel alone or additional rivaroxaban was prescribed if a high risk of arterial thromboembolism was identified or the cats experienced feline arterial thromboembolism and survived to discharge. Four cats also received pimobendan at the time of presentation, and one cat received atenolol due to formerly reported arrhythmias. In the event of feline arterial thromboembolism, enoxaparin or heparin was administered intravenously followed by subcutaneous administration. Methadone was given intravenously for pain management during hospitalization.

In the case of acute congestive heart failure, the echocardiographic examination was performed as soon as the cats were stable enough to undergo a complete echocardiographic examination. Given the retrospective nature of the study, this comprised a non-standardized time frame of administration and dosage of loop diuretics prior to the complete echocardiographic examination. Cats with chronic congestive heart failure received loop diuretics at their individually titrated dosage at the time of the echocardiographic examination, and in case of feline arterial thromboembolism, the cats received methadone prior to the echocardiographic examination.

Basic and echocardiographic parameters of the population are shown in Table 2. E-wave and A-wave were fused in five out of 25 cats with RCM and in 10 out of 25 control cats. Mean fused E-velocity was 1.19 ± 0.48 m/s for the RCM group and 0.92 ± 0.21 m/s for the control group. Of the cats with separated mitral E-waves and A-waves, the RCM group exhibited a mean E-wave-to-A-wave ratio of 3.53 ± 0.64 and the healthy controls showed a median ratio of 1.19 (range: 1.07—1.73). Cats with RCM had significantly larger LV internal diameters in both systole ($P < 0.0001$) and diastole ($P = 0.0015$), as shown in Figures 1 and 2. In four cats, systolic LV internal diameters were observed to be mildly increased [18]. Left ventricular septal ($P = 0.0084$) and posterior wall diameters ($P = 0.0072$) in diastole were significantly larger in the RCM population (Table 1), but the measurements were within the established reference range using allometric scaling. RCM cats exhibited significantly lower endocardial GLS values than healthy controls, as shown in Figure 3. All but five cats with RCM had endocardial GLS values below the established reference ranges, whereas only 11 cats had fractional shortening below the established reference despite a statistically significant difference between the groups [18,20]. A comparison of endocardial GLS tracking is shown in Figure 4. The mean GLS was −17.68% ± 4.78 with a range of −3.45% to −26.01% for the RCM cats and −28.35% ± 3.72 with a range of −22.90% to −36.49% for healthy controls. As illustrated in Figure 5, a cutoff value of −22.9% was

Table 2 Basic data and standard echocardiographic measurements of the study population.

	RCM		Control		P-value
	N	Value	N	Value	
Age (years)	25	12.68 (3.36—19.65)	25	12.91 (2.87—19.72)	0.6908
Heart rate (beats/min)	25	198.00 (150.00—221.00)	25	183.00 (149.00—236.00)	0.3464
Weight (kg)	25	4.14 (2.50—6.00)	25	4.60 (2.90—6.73)	0.8955
LA/Ao	25	2.08 ± 0.36	25	1.33 (1.00—1.50)	<0.001
LAD (mm)	25	18.90 (16.10—26.30)	25	12.73 ± 1.60	<0.001
RAD (mm)	25	15.24 ± 1.69	25	9.83 ± 0.79	<0.001
LVIDd (mm)	25	16.10 (10.50—20.60)	25	14.41 ± 1.5	0.0015
LVIDs (mm)	25	11.05 ± 2.24	25	8.60 (5.50—11.78)	<0.001
IVSd (mm)	25	4.67 ± 0.56	25	4.30 (3.20—5.00)	0.0084
IVSs (mm)	25	6.08 ± 0.94	25	6.15 (4.60—7.02)	0.9621
LVPWd (mm)	25	4.75 ± 0.45	25	4.50 ± 0.46	0.0072
LVPWs (mm)	25	6.24 ± 0.80	25	4.39 ± 0.46	0.3390
FS (%)	25	30.94 ± 11.54	25	41.17 ± 7.09	0.0201

Ao: aorta; FS: fractional shortening; IVSd: interventricular septum in diastole; IVSs: interventricular septum in systole; LA: left atrium; LAD: left atrial diameter; LVIDd: left ventricular internal diameter in diastole; LVIDs: left ventricular internal diameter in systole; LVPWd: left ventricular free wall in diastole; LVPWs: left ventricular free wall in diastole; RAD: right atrial diameter; RCM: restrictive cardiomyopathy.

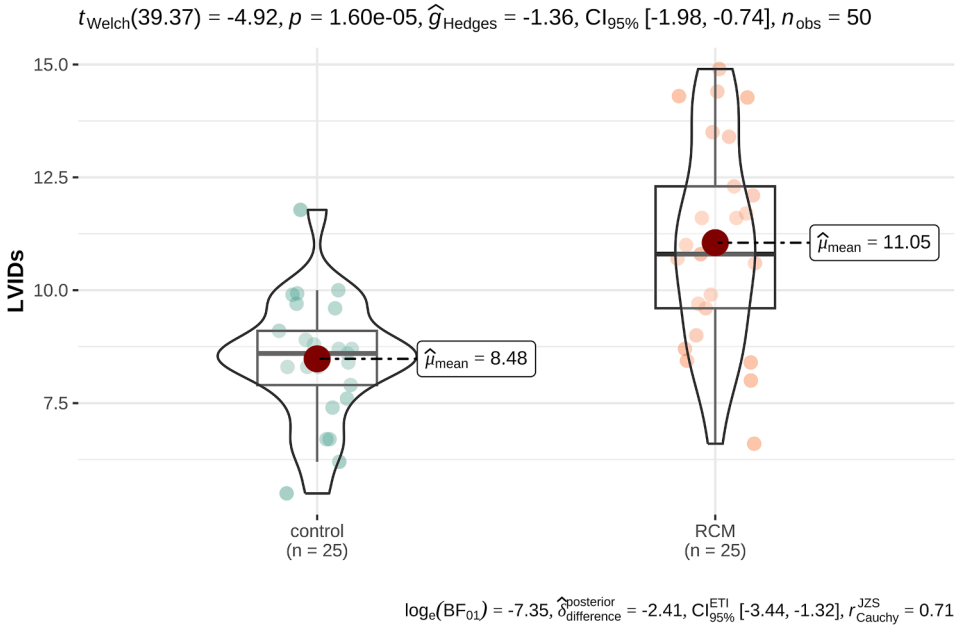

Figure 1 Comparison of left ventricular internal diameter in systole (LVIDs) of both, cats with restrictive cardiomyopathy and healthy controls. CI: confidence interval.

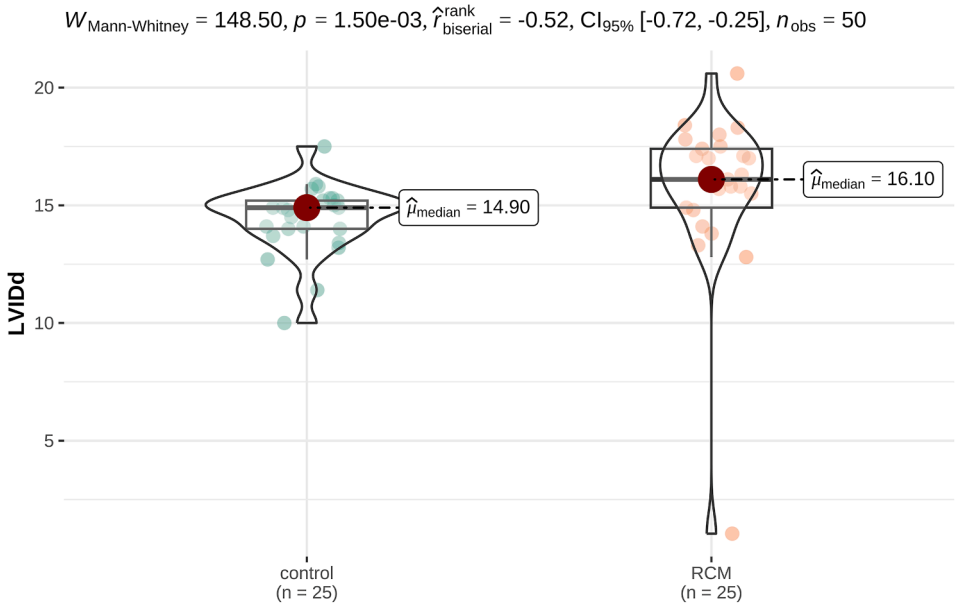

Figure 2 Comparison of left ventricular internal diameter in diastole (LVIDd) of both, cats with restrictive cardiomyopathy and healthy controls. CI: confidence interval.

identified to differentiate healthy cats from cats affected by RCM.

Discussion

Functionally, RCM induces diastolic dysfunction following myocardial or endomyocardial fibrosis. Myocardial fibrosis and scarring are known to impair not only diastolic but also systolic function in human and veterinary cardiomyopathies of various etiologies [22—26]. The present study demonstrates that cats with RCM exhibit reduced LV systolic function, as assessed by endocardial GLS. While conventional echocardiographic indices identified systolic impairment only in a subset of cases, endocardial GLS detected abnormalities in the majority of affected cats, suggesting increased sensitivity for identifying systolic dysfunction in

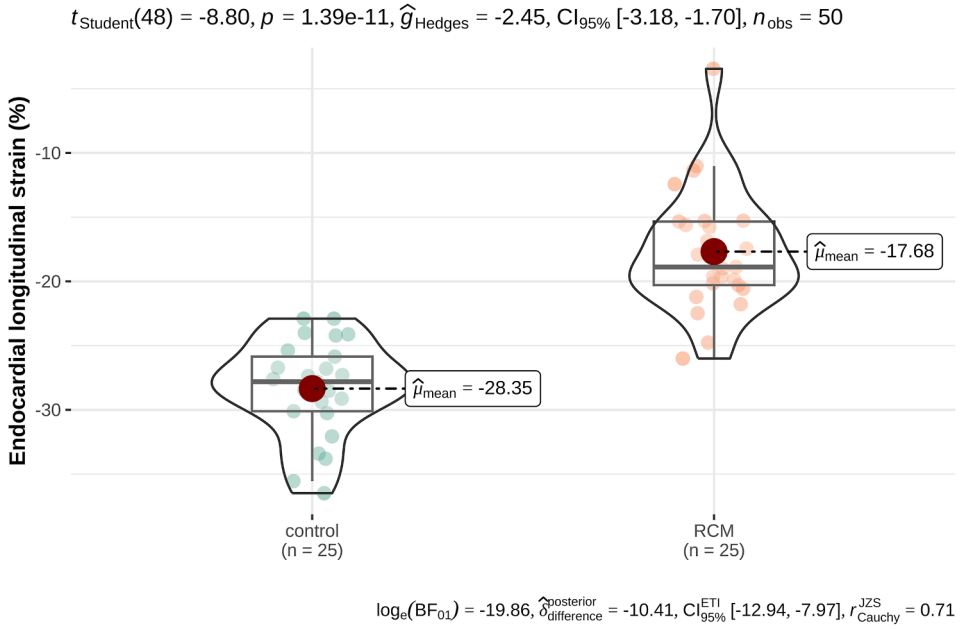

Figure 3 Comparison of endocardial global longitudinal strain of both, cats with restrictive cardiomyopathy (RCM) and healthy controls demonstrating lower strain values for cats with RCM. CI: confidence interval.

this population. Only four cats of the investigated population diagnosed with RCM had systolic LV internal diameters above established reference ranges, and only 11 cats exhibited a fractional shortening below the lower reference of 28% [18]. In contrast, 20 out of 25 cats showed an endocardial GLS value above the established reference values in our study [20].

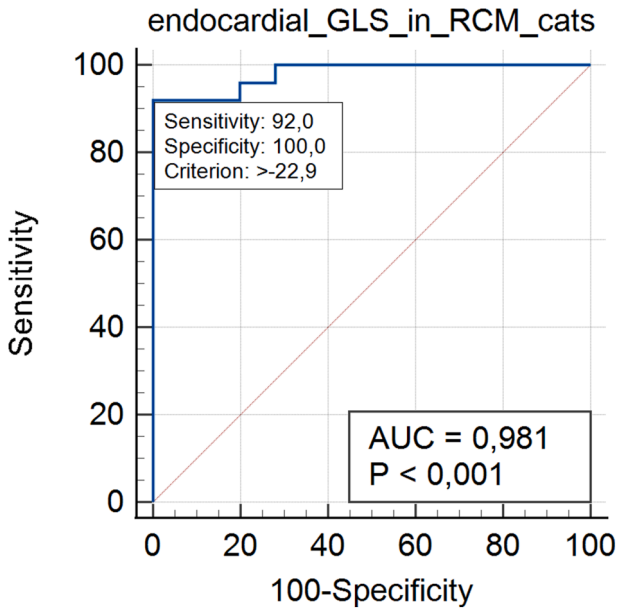

Figure 4 Tracking of three cardiac cycles of endocardial global longitudinal strain is shown for both, a cat with restrictive cardiomyopathy (RCM) and a healthy control cat. A bull's eye can be seen in the right corner of each tracing, with red segments showing normal longitudinal strain values and lighter segments showing worse longitudinal strain values seen in the tracing of the RCM affected cat. AUC: area under the curve; GLS: global longitudinal strain.

Strain analysis from two-dimensional speckle tracking has become an essential diagnostic tool in human cardiology over the past decade [27,28]. A combined left apical two-, three-, and four-chamber view for global assessment of cardiac performance is recommended in human medicine [27,29,30]. Also, in feline cardiology, it gained recognition in systolic functional assessment of felines with different cardiomyopathies [31–33]. One study performed strain analysis in cats with RCM and already suggested compromised systolic function [14]. However, only single plane strain analysis was used in that study, and patient selection might have influenced results given inclusion of cats with pulmonary hypertension and varying medication. Multiplane analysis was recently shown to be a feasible technique for feline patients [34]. Recently established feline reference values enable the application of the human standard of GLS and multiplane analysis to feline patients and showed excellent agreement of intra-observer and interobserver variability [20]. Therefore, a combined two-, three-, and four-chamber view was utilized using a specific software program[d]. As both, the investigators as well as the utilized software, were identical to those of the previous study establishing reference intervals

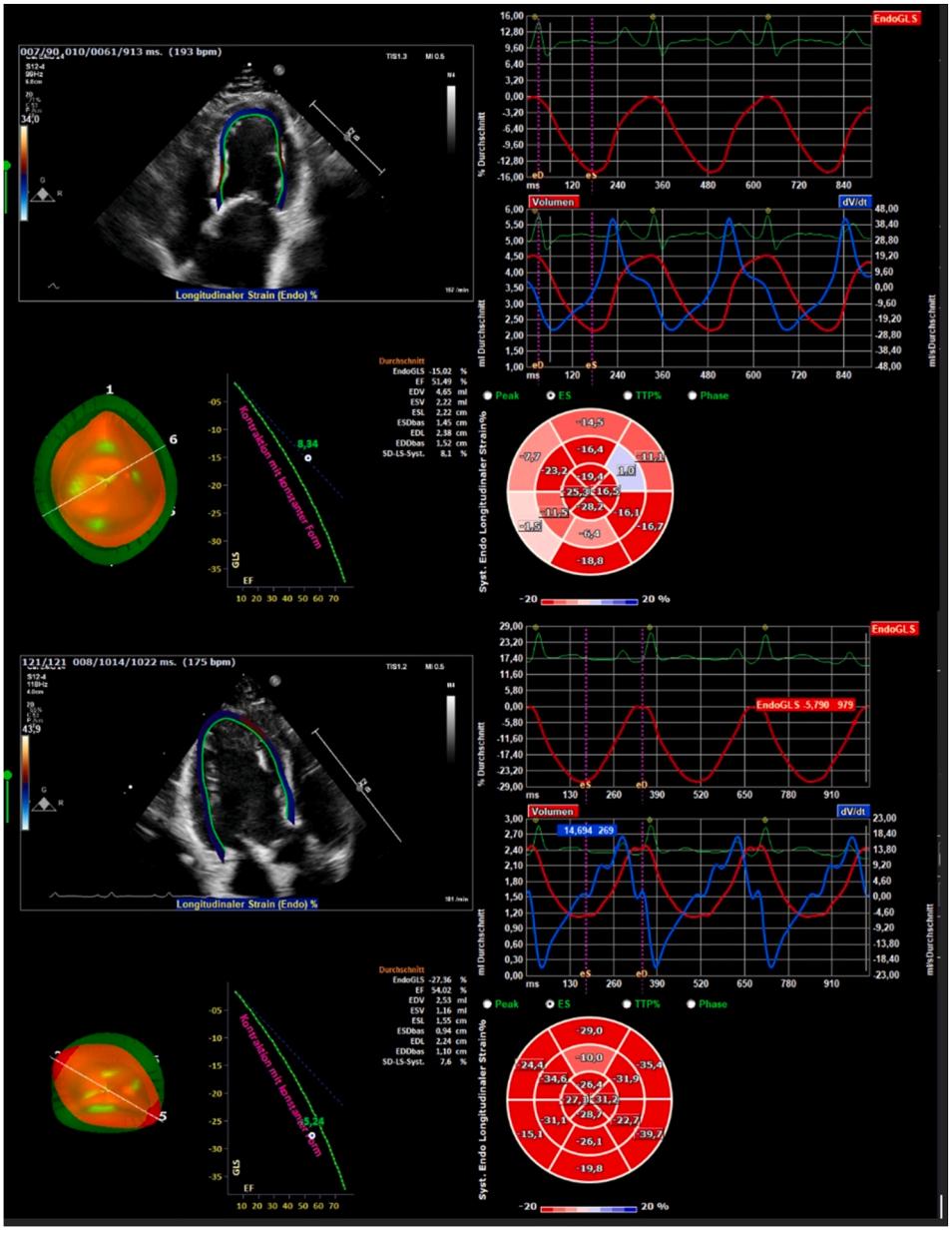

Figure 5 Receiver operating characteristic (ROC) curve demonstrating a cutoff value of −22.9% with a sensitivity of 92.00, a specificity of 100.00, and an area under the curve of 0.981. Youden index for the identified value is 0.92.

for endocardial GLS, intra-observer and interobserver variability was not assessed in the present study and should be assessed in future studies. Global over segmental analysis was chosen for improved reproducibility [28,35—37] as segmental analysis is susceptible to errors. Longitudinal strain was prioritized for its established higher sensitivity than circumferential or radial strain [28,35].

Restrictive cardiomyopathy in humans has multiple etiologies [11,21,38]. Certain conditions, such as hypereosinophilic syndrome, endomyocarditis, and endomyocardial fibroelastosis, have been associated with RCM phenotype in both humans and cats [7—9,39—41]. In our study, RCM phenotype was also combined with systemic diseases in several cases in line with the results of a previous feline study [10]. However, no histopathology has been performed to clarify possible causative etiologies. Typically, RCM does not alter ventricular wall dimensions in terms of concentric hypertrophy notably [4,21]. In this study, the RCM group had a slightly larger wall thickness than the control group, yet measurements were within the normal reference range. However, treatment dosages and time interval of administration and echocardiographic examination were not

standardized so that loading conditions cannot be excluded to influence cardiac dimensions. Preload conditions and medical treatment, particularly diuretic therapy, may have influenced both GLS measurements and ventricular wall dimensions, potentially contributing to differences between groups. Given the retrospective design and lack of standardized timing of examinations, these effects cannot be fully excluded. Our study demonstrated reduced global longitudinal systolic function with reduced endocardial GLS values in all but five RCM cats, supporting the hypothesis of compromised systolic function, as previously suggested by Suzuki et al. [14]. The present results go in line with similar findings of reduced longitudinal systolic function in humans with RCM phenotype [42]. Even though the etiologic basis of RCM might differ between species, phenotypic and functional appearance shows similarities. These findings encourage future investigations into possible treatment options.

Limitations

This study has several limitations. Its retrospective design resulted in non-standardized treatment protocols and variability in timing of echocardiographic examinations. Another limitation is the lack of histopathology to reassure the diagnosis and causative etiology of the phenotype. The functional and phenotypic classification relied solely on echocardiographic modalities. Endomyocardial biopsies would have added valuable information but are yet not standard clinical practice in feline cardiology considering risk, benefits, and therapeutic relevance. Reproducibility of GLS measurements was not assessed within this study, which limits direct evaluation of measurement variability in this specific population. However, previous studies using the same methodology have demonstrated good reproducibility [20]. Furthermore, analysis was performed by a non-blinded investigator, which may have introduced an observer bias.

Given the small size of feline hearts and abundance of false tendons, tracking of the endocardium is challenging, but with constant software improvement and gain in experience, this limitation is of decreasing importance. Finally, vendor dependency of speckle-tracking analysis and the relatively small sample size should be considered when interpreting the results. This study aims primarily at providing a base for future studies targeting systolic dysfunction in felines with RCM. Future prospective, multicenter studies with larger sample sizes, treatment standardization, and histopathology are recommended to further explore RCM, etiologies, and therapeutic options.

Conclusion

The present study demonstrated reduced endocardial GLS in cats with RCM and provides evidence for reduced systolic function in cats with RCM accordingly. Future prospective studies of appropriate sample size would be of value for further investigation.

Declaration of Competing Interest

The authors do not have any conflicts of interest to disclose.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors did not use generative AI in the preparation of this manuscript.

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