

Chordae tendineae Rupture in Dogs with Degenerative Mitral Valve Disease: Prevalence, Survival, and Prognostic Factors (114 Cases, 2001–2006)

François Serres, Valérie Chetboul, Renaud Tissier, Carolina Carlos Sampedrano, Vassiliki Gouni, Audrey P. Nicolle, and Jean-Louis Pouchelon

Background: Degenerative mitral valve disease (MVD) is the most common heart disease in small breed dogs, and *chordae tendineae* rupture (CTR) is a potential complication of this disease. The survival time and prognostic factors predictive of survival in dogs with CTR remain unknown.

Hypothesis: The prevalence and prognosis of CTR in dogs with MVD increases and decreases, respectively, with heart failure class.

Animals: This study used 706 dogs with MVD.

Methods: The diagnosis of CTR was based on a flail mitral leaflet with the tip pointing into the left atrium during systole, which was confirmed in several 2-dimension imaging planes using the left and right parasternal 4-chamber views.

Results: CTR was diagnosed in 114 of the 706 dogs with MVD (16.1%) and most of these (106/114, 93%) had severe mitral valve regurgitation as assessed by color Doppler mode. CTR prevalence increased with International Small Animal Cardiac Health Council (ISACHC) clinical class (i.e., 1.9, 20.8, 35.5, and 69.6% for ISACHC classes Ia, Ib, II, and III, respectively [$P < .05$]). Long-term follow-up was available for 57 treated dogs (angiotensin-converting enzyme inhibitors and diuretics) and 58% of these (33/57) survived >1 year after initial CTR diagnosis (median survival time, 425 days). Clinical class, the presence of ascites or acute dyspnea at the time of diagnosis, heart rate, plasma urea concentration, and left atrial size were predictors of survival.

Conclusions and Clinical Relevance: CTR is associated with a higher overall survival time than previously supposed. Its prognosis mostly depends on a combination of clinical and biochemical factors.

Key words: Canine; Doppler; Echocardiography; Heart; Mitral regurgitation.

Chordae tendineae (CT) are major components of the atrioventricular valve apparatus, and their involvement in any pathologic condition can compromise proper closure of the entire valve.^{1,2} The tips of the anterior (or septal) and posterior (or parietal) mitral leaflet are anchored to papillary muscles by first order CT. Second order CT are present between the midventricular surface of both cusps and papillary muscles. Finally, third order CT are found between the parietal (and commissural) leaflet(s) and the ventricular wall. Numerous descriptions of CT rupture (CTR) can be found in the literature, associated in most cases with underlying cardiac disease, such as valvular degeneration, endocarditis, or papillary muscle infarctus in humans.^{3,4} Historically, sectioning of the first order CTR of the anterior leaflet has been used in experimentally induced models of acute heart failure.⁵ Experimental disruption of all or part of the mitral subvalvular apparatus induces progressive systolic dysfunction because CT are important components of left ventricular geometry and function.⁶

Degenerative mitral valve disease (MVD) is characterized by valvular degeneration and is the most commonly acquired heart disease in small-sized dogs.^{7–10} It results in mitral valve insufficiency, which may in turn lead to left atrial and ventricular dilatation and, at a later stage, pulmonary edema. CT rupture is classically described as a devastating complication of canine MVD responsible for acute left heart failure, which commonly results in pulmonary edema and death despite aggressive medical therapy.^{1,2} However, to the authors' knowledge, the survival time and prognostic factors predictive of survival in dogs with MVD-associated CTR remain unknown.

The aims of the present study therefore were (1) to retrospectively assess the prevalence of CTR in dogs with MVD, (2) to document the epidemiologic characteristics, clinical and echo-Doppler findings, and survival times associated with CRT, and (3) to identify factors influencing long-term prognosis.

Materials and Methods

Animals

Case records of dogs (treated or untreated, $n = 706$) that had undergone a complete echocardiographic and Doppler examination leading to the diagnosis of MVD between January 2001 and April 2006 at the Cardiology Unit of Alfort by a trained observer (Dipl. ECVIM, resident, or PhD: VC, APN, VG, FS, CCS), were reviewed retrospectively. Dogs diagnosed with CTR were selected from the 706 echo-Doppler records. In addition, complete echocardiographic and Doppler examinations ($n = 604$) performed by the same observers during the same period and leading to a diagnosis other than MVD were reviewed to identify other potential causes of CTR.

The diagnosis of MVD was based on the following criteria: (1) left systolic apical heart murmur of late appearance (age >1 year

From the Unité de Cardiologie d'Alfort (Serres, Chetboul, Sampedrano, Gouni, Nicolle, Pouchelon), UMR INSERM U660 (Chetboul, Tissier, Pouchelon), Unité de Pharmacie-Toxicologie (Tissier), Ecole Nationale Vétérinaire d'Alfort, Maisons-Alfort cedex, France.

Reprint requests: Valérie Chetboul, DVM, PhD, Dipl. ECVIM-CA (Cardiology), Unité de Cardiologie, Ecole Nationale Vétérinaire d'Alfort, 7 avenue du Général de Gaulle, 94 704 Maisons-Alfort cedex, France; e-mail: vchetboul@vet-alfort.fr.

Submitted June 28, 2006; Revised September 5, 2006; Accepted November 8, 2006.

Copyright © 2007 by the American College of Veterinary Internal Medicine

0891-6640/07/2102-0009/\$3.00/0

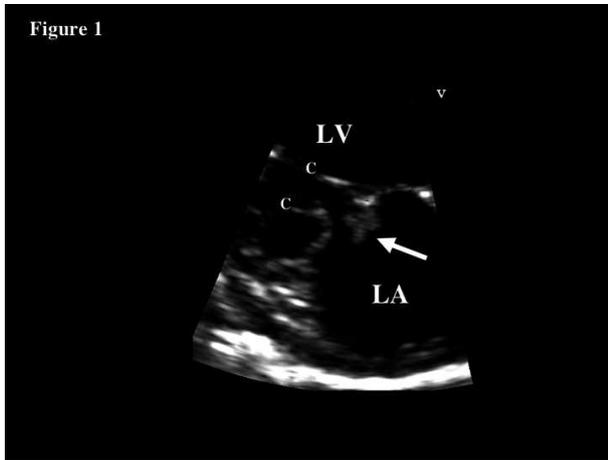


Fig 1. A 2-dimensional echocardiogram (right parasternal 4-chamber view) obtained from a dog with *chordae tendineae* rupture. The flail anterior mitral valve leaflet (arrow) is pointing back toward the left atrial chamber during systole. C, *chordae tendineae*; LA, left atrium; LV, left ventricle.

old), (2) no history of infectious disease, and (3) echocardiographic and Doppler signs of MVD including irregular and thickened mitral valve leaflets observed on the right parasternal 4-chamber view and a color-flow jet of systolic mitral insufficiency in the left atrium on the left parasternal 4-chamber view. CTR diagnosis was based on detection of a mitral valve flail with the leaflet tip pointing back into the left atrium during systole, confirmed in several 2-dimensional (2-D) imaging planes using the left and right parasternal 4-chamber views (Fig 1).¹¹

Entry time was considered as the time of the first echocardiographic examination confirming CTR diagnosis. Treatment, clinical signs, and biochemical results at the time of diagnosis were analyzed, and the degree of heart failure was classified according to International Small Animal Cardiac Health Council (ISACHC) recommendations.¹² Echocardiographic and Doppler findings also were analyzed. Follow-up evaluation was retrospectively assessed, when available, including the status (survivor or nonsurvivor) at the time of the last visit. Dogs were included as survivors (S) for the statistical analysis if CTR had been diagnosed >1 year before death or the cut-off date for statistical analysis. Dogs were included as nonsurvivors (NS) for statistical analysis if they died of signs related to the heart disease <1 year after the initial diagnosis of CTR and before the cut-off date. The cause of death in S and NS dogs was recorded as either related or unrelated to the heart disease, with dogs that died from causes unrelated to the heart disease being removed from statistical analysis. Only those dogs that underwent euthanasia because of heart failure were included in the analysis. The cut-off date for survival analysis was May 1, 2006.

Echocardiographic and Doppler Examinations

Echocardiographic and Doppler examinations were carried out in standing, awake animals with continuous ECG monitoring using ultrasound units^a equipped with 7.5–10 MHz, 5–7.5 MHz, and 2–5 MHz phased-array transducers as previously described and validated at the unit.¹³

Echocardiography. Ventricular measurements were taken from the right parasternal location using the 2-D-guided M-mode¹⁴ according to the recommendations of the American Society of Echocardiography,¹⁵ and the fractional shortening then was calculated. The aorta and left atrium were measured by the 2-D

method,¹⁶ and the left atrium/aorta ratio (LA/Ao) was calculated. The left apical 4-chamber view was used to assess mitral regurgitation semiquantitatively by measuring the size of the systolic color-flow jet originating from the mitral valve and spreading into the left atrium. The images were carefully analyzed frame-by-frame to compute the maximal area of the regurgitant jet signal (ARJ).¹⁷ The left atrium area (LAA) was measured by computerized planimetry in the same frame in which the maximal ARJ had been determined. The ARJ/LAA ratio then was calculated. Using this Doppler method, the presence of either mild ($ARJ/LAA < 30\%$), moderate ($30\% \leq ARJ/LAA \leq 70\%$), or severe ($ARJ/LAA > 70\%$) mitral regurgitation was identified by color flow. Doppler-derived evidence of systolic and diastolic pulmonary arterial hypertension (PAH) was obtained as previously described.¹⁸ Color flow Doppler examination was used to identify diastolic pulmonic and tricuspid regurgitant flows, which then were quantitatively assessed by continuous-wave Doppler examination. A telediastolic peak pulmonic insufficiency velocity ≥ 2 m/s and peak tricuspid insufficiency velocity ≥ 2.5 m/s were considered indicative of diastolic and systolic PAH. The modified Bernoulli equation ($\Delta P = 4 \times \text{velocity}^2$) was applied to the maximal velocity of telediastolic pulmonic and tricuspid insufficiency to calculate the diastolic and systolic gradients across the pulmonic and tricuspid valves, respectively. Systolic pulmonary arterial pressure then was calculated by adding the estimated right atrial pressure to the systolic RV-to-RA pressure gradient. The estimated right atrial pressure was 5 mmHg in patients with a nondilated right atrium, 10 mmHg in those with an enlarged right atrium but no right-sided heart failure, and 15 mmHg in those with right-sided heart failure.¹⁹ Dogs were categorized as having mild (SPAP = 30–50 mmHg), moderate (SPAP = 51–75 mmHg) or severe systolic PAH (SPAP >75 mmHg).

Statistical Analysis

Data are expressed as mean \pm SD. Statistical analyses were performed using the statistical software StatView.^b The prevalence of CTR in the different ISACHC classes was compared by a χ^2 test. Survival curves were based on the Kaplan-Meier method and were compared using the Log rank test. Dogs that died as a result of noncardiac diseases were censored in this analysis. Age, body weight, heart rate, and echo-Doppler parameters in the S and NS groups were compared using unpaired Student's *t* test. The distributions of the plasma urea and creatinine concentrations in the S and NS groups were skewed and therefore were compared using the nonparametric Mann-Whitney test with a selected level of significance of $P < .05$.

Results

Prevalence of CTR in Dogs with MVD ($n = 706$) and in Dogs with Other Heart Diseases ($n = 604$)

CTR was identified in 114 of the 706 dogs (16.1%) with MVD and in only 1 of the 604 animals with another diagnosis (infective endocarditis caused by *Streptococcus* sp). In most dogs (97/114, 85.1%), MVD was suspected (auscultation of left apical heart murmur) or confirmed (echo-Doppler examination) several days to months before the diagnosis of CTR. Treatment status at the time of CTR diagnosis was known for 94 of the 114 dogs: 12 dogs (12.8%) were untreated, and 82 (87.2%) received 1 or a combination of the following drugs: angiotensin-converting-enzyme (ACE) inhibitors such as benazepril, enalapril, imidapril, or ramipril (75/94 dogs, 79.8%); furosemide (45/94 dogs, 47.9%); spironolactone

Table 1. Epidemiologic characteristics of dogs with ruptured *chordae tendineae* (n = 114).

Epidemiologic Characteristics	
Sex	
Male	64.0% (73/114)
Female	36.0% (41/114)
Age	
0–5 years	0% (1/114)
5–10 years	8.8% (10/114)
>10 years	91.2% (104/114)
Breed	
Small breeds (<10 kg) 6.7 ± 1.9 kg	
Poodle	34.2% (39/114)
Cavalier King Charles Spaniel	9.6% (11/114)
Yorkshire Terrier	8.8% (10/114)
Bichon	8.8% (10/114)
Shih-tzu	3.5% (4/114)
Pekingese	3.5% (4/114)
Other small breeds	20.2% (23/114)
Total small breeds	88.6% (101/114)
Medium-sized breeds (10–25 kg) 14.3 ± 2.4 kg	
Epagneul Breton	2.6% (3/114)
Other medium-sized breeds	8.8% (10/114)
Total medium-sized breeds	11.4% (13/114)

(22/94 dogs, 23.4%); pimobendan (10/94 dogs, 10.6%); and digoxin (2/94 dogs, 2.1%).

Epidemiologic Characteristics of Dogs with CTR (n = 114): Breed, Age, and Sex

The epidemiologic characteristics of dogs with CTR are presented in Table 1. The dogs with CTR mainly consisted of male, (n = 73, 64.0%), older adult dogs (12.2 ± 2.0 years; range 6–17 years) of small breeds weighing <10 kg (n = 101, 88.6%). Only 11.4% (13/114) of the 114 dogs with CTR were medium-sized (body weight, 10–25 kg), and no large-breed dogs (body weight >25 kg) were represented.

Clinical and Echo-Doppler Findings in Dogs with CTR (n = 114)

As shown in Table 2, 24.6% (28/114) of the dogs with CTR were asymptomatic and were therefore assigned to ISACHC classes Ia and Ib at the time of diagnosis. The CTR in these 28 animals was diagnosed fortuitously when the asymptomatic left apical systolic heart murmur was explored by echo-Doppler examination. The remaining 86 dogs were symptomatic and assigned to ISACHC classes II or III. Chronic cough (49/86, 57.0%) and acute dyspnea (40/86, 46.5%) were by far the most common clinical signs in these animals, with exercise intolerance (14/86, 16.3%) and ascites (7/86, 8.1%) occurring less frequently.

A significant ($P < .01$) increase in CTR prevalence was observed with increasing ISACHC class: 1.9, 20.8, 35.5, and 69.6% for ISACHC classes Ia, Ib, II, and III, respectively (Table 2). CTR was not detected in any of the total population of dogs with mild regurgitant jet size (n = 271, Table 2). Conversely, most of the dogs with CTR (106/114, 93.0%) exhibited severe mitral valve regurgitation characterized by ARJ/LAA > 70% as assessed by color Doppler mode (100 ± 10%, range 70–100%). The other 8 dogs had moderate ARJ/LAA values (55 ± 14%, range 40–68%).

In most of the dogs with CTR (110/114, 96.5%) the ruptured CT had been attached to the anterior mitral valve leaflet. Only 4 dogs (3.5%) revealed rupture of the CT anchored to the posterior leaflet. Diastolic PAH was evidenced by Doppler examination in 6 of the 114 dogs (5.3%) with CTR (diastolic gradient, 19.8 ± 6 mmHg; range 16–29 mmHg), and systolic PAH was evidenced in 40 of the 114 dogs (35.1%, systolic pulmonary arterial pressure, 64.0 ± 23.2 mmHg; range 30–123 mmHg). The total prevalence of PAH in dogs with CTR therefore was 35.1%. All dogs with Doppler evidence of diastolic PAH simultaneously presented with Doppler evidence of systolic PAH. Diastolic pulmonary arterial pressure could not be estimated in the other 34 dogs with Doppler evidence of systolic PAH because of the absence of diastolic pulmonic regurgitant flow. Systolic PAH was considered mild in 14/40 dogs (35.0%),

Table 2. Prevalence of ruptured *chordae tendineae* in the population of 706 dogs with mitral valve disease, according to International Small Animal Cardiac Health Council (ISACHC) heart failure classes and severity of mitral regurgitation assessed by color Doppler mode.

	Heart Failure Class/Severity of Mitral Regurgitation	Cases with Complete Echo-Doppler Examination (n)	Cases with Echographic Evidence of Ruptured <i>Chordae Tendineae</i>	
			(n)	(%)
ISACHC classification	ISACHC class Ia	412	8	1.9%
	ISACHC class Ib	96	20	20.8%
	ISACHC class II	152	54	35.5%
	ISACHC class III	46	32	69.6%
Mitral regurgitant jet size	Mild (ARJ/LAA < 30%)	271	0	NA
	Moderate (30% ≤ ARJ/LAA ≤ 70%)	119	8	6.7%
	Severe (ARJ/LAA > 70%)	316	106	33.5%

ISACHC, International Small Animal Cardiac Health Council; ARJ/LAA, atrial regurgitant jet/left atrial area; n, number of cases; %, percentage of dogs in the corresponding class; NA, not applicable.

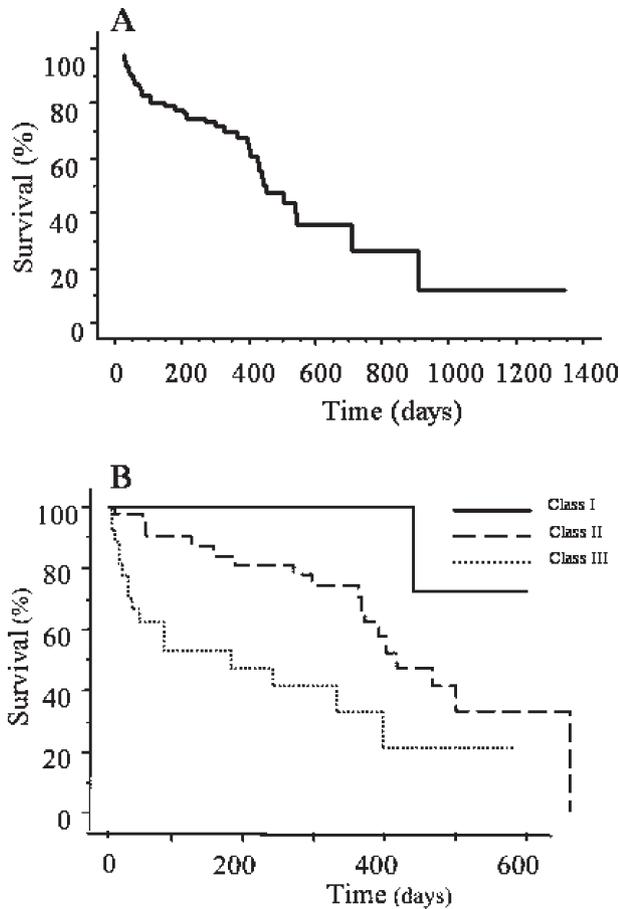


Fig 2. Survival curves obtained in the entire population of dogs diagnosed with *chordae tendineae* rupture (A) and according to International Small Animal Cardiac Health Council class (B): classes I (solid line), II (dashed line), and III (dotted line). CTR, *chordae tendineae* rupture.

moderate in 10/40 dogs (25.0%), and severe in 16/40 dogs (40%).

Follow Up and Survival of Dogs with CTR

Of the 114 dogs with CTR, follow-up was available for Kaplan-Meier analysis for 97 dogs. Out of these 97 dogs, 36 died during the study period for reasons related to the heart disease. Forty-four other dogs still were alive at the end of the study. Lastly, 17 dogs died from noncardiac-related causes and therefore were censored in the Kaplan-Meier analysis. The median survival time (Fig 2A) in the overall population of dogs with CTR ($n = 114$) was 425 days (range 5–1,324 days). As illustrated in Figure 2B, survival time decreased as ISACHC class increased. Median survival time was significantly higher ($P < .05$) in ISACHC class II than in class III (417 and 191 days, respectively). Median survival in all symptomatic dogs (combined ISACHC classes II and III) was 394 days (range 5–685 days). Survival of dogs with ascites or dyspnea at the beginning of the study as compared to other dogs also was significantly altered (Fig 3). The survival rates in ISACHC class I dogs at 1 and 2 years were 100% and 75%, respectively. Owing to

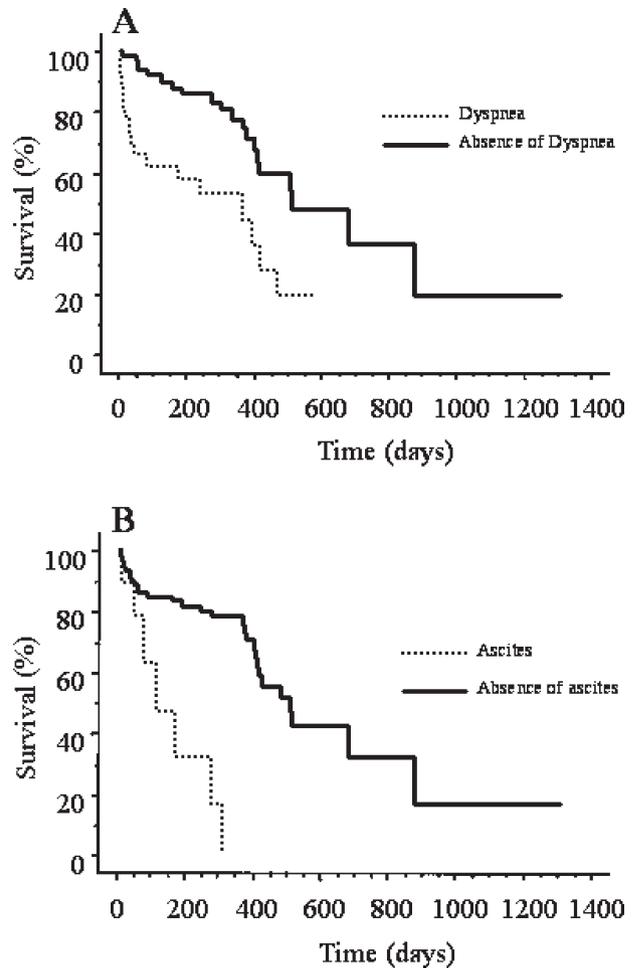


Fig 3. Survival curves for dogs diagnosed with *chordae tendineae* rupture with (dotted line) or without (solid line) dyspnea (A), and with (dotted line) or without (solid line) ascites at presentation (B). CTR, *chordae tendineae* rupture.

the high proportion of dogs from ISACHC class I that still were alive at the end of the study period, median survival in this heart failure class was not evaluated (15/28 animals were alive at the end of the study, and death was related to cardiac disease in only 2 dogs). Survival of Poodle dogs (the main investigated breed) was similar to that of other canine breeds, which were not evaluated separately because of smaller numbers.

Of the 114 dogs with CTR, only 57 were included in the survivor-nonsurvivor analysis because other dogs either died of noncardiac diseases (17 dogs) or did not have sufficient follow-up (40 dogs, including 17 dogs without any follow-up and 23 dogs still alive at the end of the study but with <1 year follow-up). The survivor-nonsurvivor analysis included 24 dogs that died or were euthanized for reasons related to heart disease <1 year after CTR diagnosis and that, therefore, were assigned to the NS group. It also included 33 dogs that still were alive >1 year after the initial CTR diagnosis that, therefore, belonged to the S group. In this last group, 12 dogs died >1 year after the CTR diagnosis; the remaining 21 dogs were alive at the end of the study

Table 3. Continuous variables and survival of dogs with ruptured *chordae tendineae* (n = 57).

Variable	P Value	Mean ± SD in S Dogs (n = 33)	Mean ± SD in NS Dogs (n = 24)
Heart rate	9.10 ⁻⁵	130.0 ± 22.0 bpm	155.0 ± 21.5 bpm
Plasma urea	.0035	0.6 ± 0.5 g/L	0.9 ± 0.46 g/L
LA/Ao ratio	.019	1.4 ± 0.54	2.0 ± 0.59
Plasma creatinine	.22	11.8 ± 5.2 mg/L	15.2 ± 13.9 mg/L
Body weight	.55	8.6 ± 3.6 kg	8.0 ± 3.9 kg
Age	.75	12.1 ± 2.4 years	12.3 ± 1.9 years
Fractional shortening	.78	51.4 ± 6.1%	48.4 ± 6.4%
DE-PASP	.89	63 ± 33 mmHg	61 ± 23 mmHg
Furosemide dosage	.94	2.5 ± 1.3 mg/kg/day	2.5 ± 1.0 mg/kg/day

S, Survivor group, i.e., dogs surviving at least 1 year after the initial diagnosis of ruptured *chordae tendineae*; NS, nonsurvivor group, i.e., dogs that died of cardiac-related cause <1 year after the initial diagnosis of ruptured *chordae tendineae*; LA/Ao, left atrial/aortic root ratio; DE-PASP, Doppler-evidenced pulmonary arterial systolic pressure.

period. All the followed animals (n = 57) were under treatment at the time of (n = 20) or before (n = 37) CTR diagnosis and received an ACE inhibitor (benazepril in 46 dogs, enalapril in 6 dogs, imidapril in 3 dogs, and ramipril in 2 dogs) either alone (n = 2 dogs, 1 in stage Ia and 1 in stage Ib) or associated with (n = 55) a diuretic (furosemide, spironolactone, or both). The overall probability of survival at 1 year for the 57 dogs of the S and NS groups was 52.6%. The mortality rates at 1, 3, and 6 months were 15.8% (9/57 dogs), 28.1% (16/57 dogs), and 31.6% (18/57), respectively. All animals in the S and NS groups assigned to ISACHC class I at the time of diagnosis belonged to the S group (4 dogs in class Ia and 6 dogs in class Ib), which also included 20/33 dogs (60.6%) and 3/33 dogs (9.1%) assigned to ISACHC classes II and III, respectively. Conversely, most NS dogs were assigned to ISACHC class III at the time of diagnosis (15/24 dogs, 62.5%), and the remaining 9 NS dogs were assigned to class II (37.5%). Heart rate at diagnosis, plasma urea concentration, and LA/Ao ratio differed significantly between the S and NS groups, suggesting that these parameters could be prognostic indicators (Table 3). No differences related to age, body weight, pulmonary arterial systolic pressure, initial dosage of furosemide, plasma creatinine concentration, and fractional shortening were found between the S and NS dogs.

Discussion

Two-dimensional echocardiography has been described as superior to M-mode in identifying flail cusps associated with CTR.¹¹ For the last 5 years, each echocardiographic examination at the Cardiology Unit of Alfort has included a routine 2-D slow-motion examination of the left mitral valve leaflets to permit systematic CTR detection. To the authors' knowledge, this report is the first to assess the prevalence of CTR in a large canine population with MVD and to analyze the influence of several epidemiologic, clinical, biochemical, and echo-Doppler factors on survival.

A few reports with a limited number of cases of CTR clinically diagnosed by either 2-D¹¹ (n = 4) or M-mode^{11,20} (n = 1) echocardiography have already been

published. Another study focused on clinical and pathologic findings in 28 dogs with spontaneous CTR,³ based on the detection of CTR during post-mortem examinations. In the study, the authors described 2 different clinical forms of CTR: one-third of the dogs had a history of acute pulmonary edema without known pre-existing heart diseases, and the others had a history of chronic symptomatic or asymptomatic known MVD. Similarly, most of the dogs in this study (85%) also presented with a history of MVD.

MVD was the unique cause of CTR in the present study except for 1 dog, and the echo-Doppler findings suggested moderate to severe valvular disease. More than 90% of the dogs with CTR had severe regurgitation jets as assessed by color Doppler mode with ARJ/LAA ratios >70%, and minimal ARJ/LAA in the remaining dogs was 40%. Moreover, more than one-third of the dogs with CTR revealed Doppler-evidenced PAH. However, high systolic pulmonary arterial pressure, which is an important prognostic factor in humans,²¹ was not predictive of survival in this study. Nevertheless, the presence of ascites, which is a consequence of PAH, was a highly significant factor that influenced survival in dogs with CTR.

Surprisingly, the survival times of dogs with CTR were comparable to those obtained in other studies that focused on canine MVD. In 1 study involving 125 dogs with symptomatic MVD at the time of diagnosis and treated with benazepril and diuretics,²² the median survival was 436 days (in this study, median survival assessed in combined ISACHC classes II and III with comparable medical treatment was 394 days).

Although most of the dogs in this study presented with moderate to severe signs of heart failure (75.4% were in ISACHC classes II or III), CTR also was identified in numerous asymptomatic dogs with MVD. Several of those dogs (7%) even revealed a normal LA/Ao ratio (ISACHC classes Ia), despite marked mitral valve regurgitation (ARJ/LAA range, 53–100%). Several factors may explain this wide range of clinical presentation. First, the echocardiographic examination for mitral flail in dogs with rupture of the first or second order CT is very similar, although the pathologic

consequences and therefore the clinical signs and survival may be different.⁵ Second, the location of the rupture on the anterior or posterior mitral leaflet may have different pathophysiologic consequences. However, because very few cases (4 out of 114) revealed mitral flail of the posterior leaflet, this parameter probably had little effect on survival. Last, duration of the underlying disease and treatment at the time of diagnosis also may have an effect on clinical presentation. For example, 5/10 dogs in ISACHC class I at the time of CTR diagnosis were already under treatment (ACE inhibitor). Whether this previous treatment influenced survival time and the absence of clinical signs at the time of diagnosis should be investigated in further prospective studies.

The finding that ascites and acute dyspnea were prognostic factors in the present study is not surprising, as both parameters have already been described to influence survival in dogs with congestive heart failure secondary to dilated cardiomyopathy.²³ The existence of azotemia as a prognostic factor is not surprising either. The marked impact of renal function on heart disease progression has been demonstrated in humans. Renal dysfunction often is observed in heart failure patients and is associated with adverse prognosis. Both proteinuria and a decline in glomerular filtration rate have been shown to be independent risk factors for the development or worsening of cardiovascular diseases.^{24,25} Treatment (especially furosemide) might have interfered with the plasma urea concentration as most dogs ($n = 20/57$) were treated at the time of diagnosis. However, the furosemide dosages did not differ significantly between S and NS dogs.

As a retrospective study, this report has several limitations. First, because pulmonic or tricuspid regurgitant flow may not always be present in animals with PAH, the true prevalence of PAH in dogs with CTR may have been underestimated. Second and importantly, because the diagnosis of CTR was based on echographic examination and not on postmortem examination, some of the dogs with fulminating heart failure secondary to CTR probably were not included in this study because they might have died before admission or during emergency treatment (ie, before echo-Doppler examination could be performed). The clinical entity previously described by Ettinger and Buegelt³ (ie, dogs presenting with acute fulminant pulmonary edema without preexistent known cardiac disease), therefore, was not found in the present study. Last, the absence of postmortem examination also may be a limitation because CTR could not be confirmed by direct inspection. The accuracy of transthoracic echocardiographic detection of CTR in the dog has never been evaluated and it could be hypothesized that, although most unlikely, severe mitral leaflet prolapses and not CTR might have been included in the study sample, leading to a possible overestimation of disease prevalence.

In conclusion, CTR is associated with a higher overall survival time than previously supposed. Its prognosis mostly relies on combined clinical and biochemical factors. Prospective studies should be carried out

to determine if early therapy of dogs with MVD is beneficial (ie, prevents the development of congestive heart failure or PAH, improves clinical outcome, or even has a life-prolonging effect when CTR is present).

Footnotes

^a Vingmed system 5, Vivid 5 and Vivid 7, General Electric Medical System, Waukesha, WI and Horten, Norway

^b Statview, SAS institute, Cary, NC

Acknowledgments

This research was supported by the resident grant program of Vetoquinol pharmaceutical laboratory (BP 189, 70204 Lure cedex, France). The Vivid 7 ultrasound system was sponsored by Novartis Animal Health (92500 Rueil Malmaison, France).

References

1. Kittleson MD, Kienle RD. Myxomatous atrioventricular valvular degeneration. In Kittleson MD, Kienle RD, eds. *Small Animal Cardiovascular Medicine*. Saint Louis, MO: Mosby; 1998:297–318.
2. Sisson D, Kwart C, Darke PGG. Acquired valvular heart disease in dogs and cats. In: Fox PR, Sisson D, Moise NS, eds. *Textbook of Canine and Feline Cardiology*. Philadelphia, PA: WB Saunders; 1999:536–565.
3. Ettinger S, Buegelt CD. Ruptured chordae tendineae in the dog. *J Am Vet Med Assoc* 1969;155:535–546.
4. Fukuda N, Yuki T, Arata I, et al. Predisposing factors for severe mitral regurgitation in idiopathic mitral valve prolapse. *Am J Cardiol* 1995;76:503–507.
5. Haller J, Morrow A. Experimental mitral insufficiency: An operative method with chronic survival. *Ann Surg* 1955;142:37–51.
6. Yun KL, Niczyporuk MA, Sarris GE, et al. Importance of mitral subvalvular apparatus in terms of cardiac energetics and systolic mechanics in the ejecting canine heart. *J Clin Invest* 1991;87:247–254.
7. Thrusfield MV, Aiken CGC, Darke PGG. Observations on breed and sex in relation to canine heart valve incompetence. *J Small Anim Pract* 1985;26:709–717.
8. Kwart C, Haggstrom J. Acquired valvular heart disease. In: Ettinger SJ, Feldman EC, eds. *Textbook of Veterinary Internal Medicine*, 5th ed. Philadelphia, PA: WB Saunders; 2000:787–800.
9. Beardow AW, Buchanan JW. Chronic mitral valve disease in Cavalier King Charles spaniels: 95 cases (1987–1991). *J Am Vet Med Assoc* 1993;203:1023–1029.
10. Serfass P, Chetboul V, Carlos Sampedrano C, et al. Retrospective study of 942 small sized-dogs: prevalence of left apical systolic heart murmur and left-sided heart failure, critical effects of breed, and sex. *J Vet Cardiol* 2006;8:11–18.
11. Jacobs GJ, Calvert CA, Mahaffey MB, et al. Echocardiographic detection of flail left atrioventricular valve cusp from ruptured chordae tendinae in 4 dogs. *J Vet Intern Med* 1995;9:341–346.
12. International Small Animal Cardiac Health Council. Appendix A Recommendations for diagnosis of heart disease and treatment of heart failure in small animals. In: Fox PR, Sisson D,

Moïse NS, eds. Textbook of Canine and Feline Cardiology, 2nd ed. Philadelphia, PA: WB Saunders; 1999:883–901.

13. Chetboul V, Athanassiadis N, Concordet D, et al. Observer-dependent variability of quantitative clinical endpoint: example of canine echocardiography. *J Vet Pharmacol Therap* 2004;27:49–56.

14. Thomas WP, Gaber CE, Jacobs GJ, et al. Recommendations for standards in transthoracic two-dimensional echocardiography in the dog and cat. Echocardiography Committee of the Specialty of Cardiology, American College of Veterinary Internal Medicine. *J Vet Intern Med* 1993;7:247–252.

15. Sahn DJ, DeMaria A, Kisslo J, et al. Recommendations regarding quantitation in M-mode echocardiography: Results of a survey of echocardiographic measurements. *Circulation* 1978;58:1072–1083.

16. Chetboul V, Carlos Sampedrano C, Concordet D, et al. Use of quantitative two-dimensional color tissue Doppler imaging for assessment of left ventricular radial and longitudinal myocardial velocities in dogs. *Am J Vet Res* 2005;66:953–961.

17. Muzzi RAL, De Araújo RB, Muzzi LAL, et al. Regurgitant jet area by Doppler color flow mapping: Quantitative assessment of mitral regurgitation severity in dogs. *J Vet Cardiol* 2003;5:33–38.

18. Johnson L, Boon J, Orton EC. Clinical characteristics of 53 dogs with Doppler-derived evidence of pulmonary hypertension: 1992–1996. *J Vet Intern Med* 1999;13:440–447.

19. Kittleson MD, Kienle RD. Pulmonary arterial and systemic arterial hypertension. In: Kittleson MD, Kienle RD, eds. *Small Animal Cardiovascular Medicine*. Saint Louis, MO: Mosby; 1998:433–449.

20. Olivier NB, Kittleson MD, Eyster G, et al. M-mode echocardiography in the diagnosis of ruptured mitral chordae tendinae in a dog. *J Am Vet Med Assoc* 1984;184:588–589.

21. Cooper R, Ghali J, Simmons BE, et al. Elevated pulmonary artery pressure. An independent predictor of mortality. *Chest* 1991;99:112–120.

22. The BENCH study group. The effect of benazepril on survival times and clinical signs of dogs with congestive heart failure: Results of a multicenter, prospective, randomized, double-blinded, placebo controlled, long-term clinical trial. *J Vet Cardiol* 1999;1:7–18.

23. Tidholm A, Svensson H, Sylvén C. Survival and prognostic factors in 189 dogs with dilated cardiomyopathy. *J Am Anim Hosp Assoc* 1997;33:364–368.

24. Smith GL, Lichtman JH, Bracken MB et al. Renal impairment and outcome in heart failure. Systematic review and meta-analysis. *J Am Coll Cardiol* 2006;47:1987–1996.

25. Bongartz LG, Cramer MJ, Doevendans PA, et al. The severe cardiorenal syndrome: 'Guyton revisited'. *Eur Heart J* 2005;26:11–17.