ECG of the Month

A 5-year-old 28.9-kg (63.6-lb) neutered male Boxer was referred to the Veterinary Medical Teaching Hospital at Texas A&M University for evaluation of an arrhythmia that was ausculted during routine physical examination. Two episodes of syncope had occurred 2 days prior to the evaluation. Additionally, occasional instances of cough were reported. The dog was successfully treated for heartworm infection 4 years earlier and had been given monthly heartworm preventative regularly since that time. The owner reported that the dog had a history of extreme anxiety during each visit to a veterinary hospital. At the evaluation, the dog was bright and alert. Physical examination did not reveal any signs of respiratory tract abnormalities. The dog had pink, moist mucous membranes, and capillary refill time was 2 seconds. No heart murmur was ausculted. Heart rate was approximately 160 beats/min, and an irregular rhythm was detected. Femoral pulses were strong bilaterally, but weak pulses and pulse deficits coincided with periods of tachycardia. The dog was visibly nervous at all times during its outpatient visit to the hospital.

Diagnostic tests performed included ECG, echocardiography, thoracic radiography, serum biochemical analysis, whole blood hematologic analysis, and immunofluorescence determination of serum anti–Trypanosoma cruzi antibody titer to rule out possible infection with that organism. Results of thoracic radiography revealed predominantly left-sided cardiomegaly without evidence of congestive heart failure. Echocardiographic findings included moderate to severe left atrial and left ventricular enlargement with reduced left ventricular systolic function (fractional shortening, 20% [reference range, > 23%]1,2; area shortening, 39% [reference range, > 50%]1,2). The size of the right side of the heart was considered normal. Clinopathologic abnormalities included severe hyperglobulinemia (7.2 g/dL; reference range, 2.5 to 3.8 g/dL), high plasma total protein concentration (10.6 g/dL; reference range, 7.0 to 9.0 g/dL), and mild thrombocytopenia (181,000 platelets/µL; reference range, 200,000 to 500,000 platelets/µL). The dog was seronegative for T cruzi infection. Electrocardiography was performed.

**ECG Interpretation**

Multiple ECG tracings were acquired during the evaluation. In addition to an underlying sinus rhythm, ECG revealed occasional singlet supraventricular premature complexes and ventricular premature complexes (VPCs; Figure 1). Sinus beats maintained a constant PR interval (100 milliseconds); however, QRS complex duration was prolonged (60 milliseconds), which was consistent with left ventricular enlargement. Frequent paroxysms of polymorphic ventricular tachycardia occurred, which consisted of VPCs with primarily left bundle branch block (LBBB) morphology, R-on-T phenomenon, and an instantaneous heart rate of approximately 300 to 375 beats/min. Occasionally, paroxysms of ventricular tachycardia with VPCs that had LBBB morphology ended abruptly with isoelectric VPCs in the lead II tracing (Figure 1); in some instances, paroxysms occurred where the isoelectric complex morphology predominated (Figure 2). The variation in QRS complex morphology and polarity in leads I, II, and III suggested 2 sites of origin for the ventricular arrhythmias.1,3

The frequency with which the paroxysms of ventricular tachycardia occurred during echocardiography was a concern; therefore, a bolus of lidocaine hydrochloride (2 mg/kg [0.91 mg/lb], IV) was administered 3 times over an interval of 30 minutes. The number of occurrences and severity of the ventricular arrhythmias decreased.

Prior to discharge from the hospital, the dog was administered sotalol hydrochloride (0.26 mg/kg [0.118 mg/lb], PO, q 12 h) for arrhythmia control and pimobendan (0.26 mg/kg [0.118 mg/lb], PO, q 12 h) for left ventricular systolic dysfunction. An ambulatory ECG (AECG) monitor was placed on the dog for a 24-hour recording period. Two brief paroxysms of ventricular tachycardia with R-on-T phenomenon were recorded approximately 2 hours following placement of the monitor; these events occurred late in the evening while in a hotel room with

---

Contributed by Randolph L. Winter, BS; Crystal D. Harris, DVM; and Ashley B. Saunders, DVM, DACVIM; from the Department of Small Animal Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences, Texas A&M University, College Station, TX 77843.

Address correspondence to Dr. Saunders (asaunders@cvm.tamu.edu).

---

Footnotes:
1. Area shortening
2. Fractional shortening
3. Complex morphology

**Figure 1**—Initial lead II ECG trace obtained from a Boxer with left ventricular systolic dysfunction. There is an underlying sinus rhythm with singlet supraventricular premature complexes (arrowheads) and ventricular premature complexes (arrow) with left bundle branch block (LBBB) morphology. The QRS complex duration of the sinus beats is prolonged (60 milliseconds), which is consistent with an abnormally large left ventricle. A paroxysm of multiformal ventricular tachycardia occurs with an instantaneous heart rate of approximately 300 to 375 beats/min. Although the initial complexes have LBBB morphology, the paroxysm ends abruptly with 2 complexes that have a nearly isoelectric morphology. Paper speed = 25 mm/s; 1 cm = 1 mV.
the owner. No other episodes of ventricular tachycardia were recorded during the AECG evaluation.

Discussion

Arrhythmogenic right ventricular cardiomyopathy (ARVC) is a myocardial disease characterized by the development of fatty and fibrofatty infiltration of the myocardium, cardiomyocyte vacuolization, and cardiomyocyte necrosis, which result in electrical abnormalities and, in some cases, also ventricular systolic dysfunction. 4 Arrhythmogenic right ventricular cardiomyopathy in dogs, 2,5,6 cats, 7 and humans 7,8 has been reported and predominately affects the right ventricle, although left ventricular and atrial involvement are also documented. 4,10 In veterinary medicine, this cardiomyopathy has been best described in Boxers in which the disease is characterized by ventricular arrhythmias with or without accompanying clinical signs. 4 In a subset of Boxers with ARVC, a diagnosis of left ventricular myocardial dysfunction (in addition to arrhythmias) has been made; this is similar to a finding in some humans with ARVC. 7 The ventricular arrhythmias typically have a characteristic VPC morphology with a positive net deflection in lead II consistent with LBBB, thereby suggesting a right ventricular origin, although multiple morphologies (LBBB and right bundle branch block) have been reported. 2,3 The dog of this report had polymorphic ventricular tachycardia in which the morphology of the ventricular complexes in lead II was consistent with an LBBB pattern or was isoelectric, suggestive of multiple origins. In a pace-mapping study involving 12-lead ECG, it was determined that ventricular arrhythmias most likely originate from the right ventricle in affected Boxers; however, the precise origin of the ventricular arrhythmias cannot be established without epicardial and endocardial mapping.

Mutations in the ryanodine type 2 receptor (RyR2) and an associated regulatory protein, calstabin, have been identified in Boxers and humans with ARVC and result in
abnormal calcium handling within the cardiomyocytes. An increase in cardiomyocyte intracellular calcium concentration during diastole predisposes to arrhythmia formation and sudden death. Sympathetic nervous system stimulation is not reported to be a major factor influencing ventricular arrhythmia formation in humans with ARVC, although some evidence suggests that it may have an influence on ventricular arrhythmias in Boxers. In a retrospective study conducted by Scansen et al., AECC recordings from Boxers with ARVC were analyzed for a time-dependent variability in the recorded number of VPCs. There was a significant increase in the number of VPCs from 8:00 AM to 12:00 PM and 4:00 PM to 8:00 PM, compared with the number detected from midnight to 4:00 AM. Those data suggested that sympathetic nervous system stimulation may be the cause of the increased number of VPCs detected during certain periods of the day, although the severity of ventricular arrhythmias was not worse during the first hour after placing the monitor than at other time points. A well-described condition in humans is catecholaminergic polymorphic ventricular tachycardia, which is also characterized by mutations in RyR2 receptors and in a regulatory protein calstabin2. There is evidence that the RyR2 gene is associated with arrhythmogenic right ventricular cardiomyopathy in humans. The increase in cardiomyocyte intracellular calcium ion concentration during diastole that occurs secondary to catecholamine release related to stress or physical exertion in humans with CPVT predisposes them to ventricular arrhythmias and sudden death. The dog of this report had numerous episodes of polymorphic ventricular tachycardia and was anxious during its evaluation in the hospital. An AECC evaluation was performed to evaluate the frequency and severity of ventricular arrhythmias. Within the first 2 hours of the AECC recording, 2 brief episodes of ventricular tachycardia occurred. No episodes of ventricular tachycardia were evident during the remainder of the recording period, suggesting that sympathetic nervous system stimulation in the hospital may have had an affect on the number of polymorphic ventricular arrhythmias that were detected.

Sotalol, a class III antiarrhythmic medication with β-adrenergic receptor blocking properties, is efficacious in the treatment of Boxers with ARVC. For arrhythmia control in the dog of this report, administration of sotalol was commenced prior to its discharge from the hospital. β-Adrenergic receptor blockers have a negative inotropic effect and should be administered cautiously to dogs with ventricular systolic dysfunction. As a precautionary measure, treatment with pimobendan was initiated because of its positive inotropic effects. Pimobendan administration decreases morbidity and increases survival time in dogs with congestive heart failure caused by dilated cardiomyopathy. In studies evaluating dogs with congestive heart failure attributable to dilated cardiomyopathy or valvular heart disease, proarrhythmia related to pimobendan administration was not evident. Administration of sotalol prior to discharge from the hospital may have had an effect on the severity of ventricular arrhythmias recorded during 24-hour AECC in the dog of this report. The owner was given a prescription for benazepril hydrochloride (0.35 mg/kg [0.159 mg/lb], PO, q 12 h) and instructed to start administration to the dog the following day. Additional evaluation of the dog’s hyperglobulinemia consisted of long-bone radiography, plasma protein electrophoresis, and Bence-Jones protein quantification, all of which revealed no important abnormalities. Further diagnostic evaluation of the hyperglobulinemia was declined by the owner. Approximately 5 months later, the owner reported that the dog was doing extremely well at home without any exercise intolerance or collapse.

References