

# ECG of the Month

A 1-year-old 27.5-kg (60.5-lb) sexually intact male Boxer was evaluated because of right-sided congestive heart failure and exercise intolerance. Current treatments included furosemide (2.98 mg/kg [1.35 mg/lb], PO, q 8 h), benazepril hydrochloride (0.36 mg/kg [0.16 mg/lb], PO, q 12 h), spironolactone (1.1 mg/kg [0.50 mg/lb], PO, q 12 h), and hydrochlorothiazide (0.45 mg/kg [0.20 mg/lb], PO, q 12 h). At the initial referral evaluation, the dog was bright, alert, responsive, and cachexic (body condition score, 2/9). Cardiac auscultation revealed a regularly irregular rhythm with a heart rate of 130 beats/min. There was a grade 5/6 left basilar systolic murmur. The jugular veins were distended, and there was positive hepatojugular reflux. The abdomen was severely distended, and a ballotable fluid wave was easily detected. The remainder of the physical examination findings were unremarkable. A CBC revealed no abnormalities. Serum biochemical analyses revealed mildly high activity of alanine aminotransferase (125 U/L; reference range, 17 to 86 U/L) and mildly high concentrations of phosphorus (5.5 mg/dL; reference range, 2.5 to 5.3 mg/dL) and potassium (5.4 mEq/L; reference range, 3.7 to 4.8 mEq/L); all other variables were within reference ranges.

Contributed by Mandi K. Schmidt, DVM, DACVIM and Amara H. Estrada, DVM, DACVIM; from the Department of Small Animal Clinical Sciences, Veterinary Medical Center, University of Florida, Gainesville, FL 32610.

Address correspondence to Dr. Schmidt (mandi.k.schmidt@gmail.com).

Echocardiography revealed tricuspid valve dysplasia and severe pulmonic valve stenosis. The peak systolic Doppler pressure gradient across the tricuspid and pulmonic valves was approximately 160 mm Hg. There was severe tricuspid valve regurgitation, moderate pulmonic valve insufficiency, and severe right atrial and right ventricular enlargement. The left and right coronary arteries were visualized to branch normally from the aortic root. Electrocardiography was performed (Figure 1).

## ECG Interpretation

A 6-lead ECG examination revealed a regularly irregular sinus rhythm consistent with a respiratory sinus arrhythmia<sup>1</sup> (Figure 1). The mean heart rate was 100 beats/min, and the instantaneous heart rate varied from 58 to 100 beats/min. The QRS complexes were wide (0.07 seconds) and bizarre with a splintered appearance. In the lead II trace, the QRS complexes had a W-shaped appearance, which could also be labeled as an *rsr'S'r'* appearance.<sup>2</sup> A right axis deviation; presence of S waves in lead I, II, and III tracings; and S waves > 0.35 mV in lead I, II, and aVF tracings were all indicative of right ventricular enlargement.<sup>3,4</sup> The true mean electrical axis was difficult to ascertain because of the splintered nature of the QRS complexes. However, a right axis deviation with a mean electrical axis of approximately  $-140^{\circ}$  to  $-180^{\circ}$  was consistent with right-sided heart enlargement, right-sided cardiac conduc-

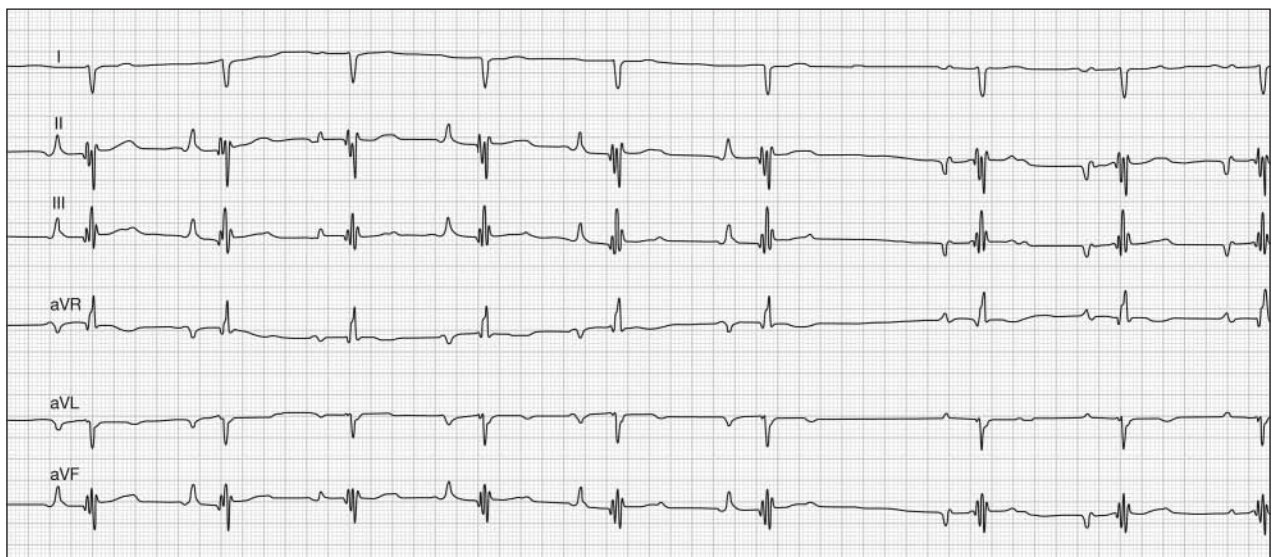


Figure 1—Six-lead ECG recording obtained from a 1-year-old Boxer that was evaluated because of right-sided congestive heart failure and exercise intolerance. Notice the regularly irregular rhythm consistent with a sinus arrhythmia. The PR interval is prolonged, indicating first-degree atrioventricular block. The QRS complexes are wide and bizarre with a splintered appearance. There is evidence of right-sided heart enlargement with a right axis shift and deep S waves. The P waves are variable in height; biphasic P waves are present at the end of the tracings, which are best seen in lead II. The biphasic P waves are primarily negative in the lead II, III, and aVF tracings, positive in the lead aVR and aVL tracings, and isoelectric in the lead I tracing. The biphasic P waves may represent ectopic atrial complexes (P') and an idioatrial rhythm, may be secondary to an enlarged and diseased right atrium with abnormal conduction, or may represent an uncommon variant of a wandering atrial or sinoatrial pacemaker. Paper speed = 50 mm/s; 1 cm = 1 mV.

tion abnormalities, or both. In the lead I trace, the QRS complexes were not splintered and negative, indicative of right axis deviation.<sup>3</sup>

The P waves were variable in size and configuration in the lead II trace. Initially, the P waves were tall and positive (0.4 to 0.5 mV; reference range, 0.2 to 0.4 mV), which is consistent with P pulmonale, or right atrial enlargement.<sup>3</sup> At the end of the lead II trace, some of the P waves were biphasic and primarily negative. It was considered that the biphasic P waves may have represented ectopic atrial complexes (P') and an idioatrial rhythm, may have occurred secondary to an enlarged and diseased right atrium with abnormal atrial conduction, or may have been indicative of an uncommon variant of a wandering atrial or sinoatrial pacemaker.<sup>1,2,5</sup> The PR interval was wide (0.14 to 0.16 seconds; reference range, < 0.13 seconds), consistent with first-degree atrioventricular block.<sup>1</sup> The PR interval for the biphasic P waves was slightly longer (0.16 seconds) than the PR interval for the upright and tall P waves (0.14 to 0.16 seconds).

Abdominal ultrasonography was also performed. The hepatic veins and caudal vena cava were severely dilated, and there was a considerable amount of fluid in the abdominal cavity. Abdominocentesis was performed, and 5.7 L of serosanguineous fluid was removed. Subsequent to fluid removal, the dog's weight was 20.6 kg (45.3 lb).

A jugular vein was used for right-sided catheterization of the heart, and balloon valvuloplasty of the stenotic pulmonary valve was performed. The procedure was completed without complication, and the dog recovered well from anesthesia. Echocardiography was performed the following day. The peak systolic Doppler pressure gradient across the pulmonic valve was reduced to approximately 54 mm Hg, which was consistent with mild to moderate pulmonic valve stenosis. Treatment with hydrochlorothiazide was discontinued, and the dog was discharged from the hospital; the owners were instructed to administer omega-3 fatty acids (approx 25 mg of docosahexaenoic acid/kg [11.36 mg/lb] and 40 mg of eicosapentaenoic acid/kg [18.18 mg/lb], PO, q 24 h) and to continue treatment with furosemide, benazepril, and spironolactone.

## Discussion

Splintering of QRS complexes is evident in ECG traces obtained from children and dogs with tricuspid valve dysplasia.<sup>4,6</sup> Electrocardiographically, tricuspid valve dysplasia of dogs commonly causes a right axis deviation, P pulmonale, and right ventricular enlargement patterns.<sup>4</sup> The underlying mechanism behind QRS splintering is unknown, but it is thought to be caused by alterations of ventricular depolarization secondary to fibrosis, bypass tracts, or ischemia.<sup>4</sup>

In the dog of this report, the presence of a regularly irregular rhythm and first-degree atrioventricular block was consistent with elevated vagal tone.<sup>1</sup> It is commonly understood that alterations of vagal activity with respiration cause the heart rate to decrease and increase with the breathing cycle in dogs.<sup>1</sup> Heart rate acceleration with inspiration and deceleration with expiration is typically interpreted as a respiratory sinus arrhythmia.<sup>1,2</sup> In the

ECG traces obtained from the dog of this report, slight positive baseline undulation was evident at the initial higher heart rate, which corresponded with inspiration in this dog. In general, increased vagal tone is unusual in dogs with heart failure, in which sympathetic tone is typically predominant.

The shape and amplitude of P waves are typically more variable in dogs than in other mammals.<sup>1,2</sup> In addition to this inherent variability, respiratory alterations of vagal tone commonly cause cyclic P wave changes in dogs.<sup>1,2</sup> The proposed causes of cyclic P wave changes during sinus rhythm in dogs include variations in the orientation of the heart within the thorax secondary to the position of the diaphragm during breathing, variations of blood volume and pressure within the right atrium associated with respiration, and variations in vagal tone that shift the depolarizing pacemaker focus cranially or caudally within the sinoatrial node.<sup>1,2</sup> This type of vagal tone-associated pacemaker shifting has been termed a wandering pacemaker within the sinoatrial node.<sup>1,2</sup> Vectorcardiography assessment in dogs has revealed a transition in pacemaker location toward the head of the sinoatrial node with a resultant increased P wave height during an inspiratory increase in heart rate.<sup>2</sup> Alternatively, shifting of the pacemaker outside the sinoatrial node to between the sinoatrial node and atrioventricular node has also been proposed as a cause of these cyclic P wave changes.<sup>1,2</sup> Electrophysiological atrial mapping in dogs has revealed 3 separate points of origin of atrial depolarization; 1 near the sinoatrial node and 2 outside the sinoatrial node and in the region of the coronary sinus or atrioventricular junction.<sup>2</sup> This specific type of transition of the depolarizing pacemaker focus is also cyclic and may result in positive, biphasic, isoelectric, or negative P waves.<sup>2</sup> Therefore, in instances of a wandering atrial pacemaker, changes in P wave morphology may result from shifts in the region of earliest activation among these 3 points, 2 of which are outside the sinoatrial node.<sup>2</sup> The marked P wave variation associated with sinus arrhythmia in dogs makes the differential diagnosis between wandering atrial pacemaker and wandering sinoatrial pacemaker speculative at best.<sup>2</sup> Ordinarily, the diagnosis of a wandering atrial pacemaker is only considered when the PR interval is abnormally shortened in association with the detection of the bizarrely shaped or reverse-polarity P waves in several leads (including leads I, II, aVF, V2, and V4).<sup>2</sup> In the dog of this report, a wandering atrial pacemaker was not considered likely because the PR interval associated with the biphasic P waves was not notably different from the PR intervals in the remainder of the ECG tracings.

In general, atrial arrhythmias secondary to cardiac disease and atrial enlargement are common in dogs.<sup>1</sup> The configuration of ectopic P' waves differs from that of sinus P waves and may be negative, positive, or biphasic.<sup>1</sup> The biphasic P waves found in the dog's ECG recordings may have represented ectopic atrial complexes and an idioatrial rhythm.<sup>1,5</sup> The abnormal biphasic P waves are described as primarily negative in leads II, III, and aVF; positive in leads aVR and aVL; and isoelectric in lead I. In humans, this type of P' wave polarity has been shown to most commonly originate from the right atrium and more specifically from the tricuspid valve annulus.<sup>7</sup> An idioatrial rhythm occurs

as a result of an ectopic atrial pacemaker combined with the reduced impulse formation or conduction of the sinoatrial node.<sup>5</sup> The high vagal tone present in the dog of this report may have suppressed the sinus node rate to a rate slightly less than the ectopic atrial pacemaker rate, thereby allowing the ectopic atrial focus to dominate the rhythm intermittently.<sup>3</sup> Recordings obtained from precordial leads can be helpful in determining the origin of ectopic atrial impulses and may have been beneficial in this case.

Balloon valvuloplasty markedly reduced the pressure overload associated with this dog's pulmonic valve stenosis. This reduction provided improved forward flow into the lungs and a reduction in the severity of right-sided congestive heart failure. Following discharge from the hospital, the dog had a dramatic improvement in exercise tolerance, began gaining weight, and required decreased dosages of diuretics for congestive heart failure management. However, the dog continued to have severe congenital heart disease secondary to tricuspid valve dysplasia, severe tricuspid valve regurgitation, and right-sided congestive heart failure and was expected to have a decreased life span.

### References

1. Tilley LP. Analysis of common canine cardiac arrhythmias. In: Tilley LP, ed. *Essentials of canine and feline electrocardiography*. 3rd ed. Philadelphia: Lea & Febiger, 1992;135–141, 169–170.
2. Detweiler DK. The dog electrocardiogram. A critical review. In: MacFarlane P, Veitch Lawrie TD, eds. *Comprehensive electrocardiology: theory and practice in health and disease*. New York: Pergamon Press, 1989;1268–1329.
3. Tilley LP. Analysis of canine P-QRS-T deflections. In: Tilley LP, ed. *Essentials of canine and feline electrocardiography*. 3rd ed. Philadelphia: Lea & Febiger, 1992;60–68, 78.
4. Kornreich BG, Moise SN. Right atrioventricular valve malformation in dogs and cats: an electrocardiographic survey with emphasis on splintered QRS complexes. *J Vet Intern Med* 1997;11:226–230.
5. Achen SE, Saunders AB, Miller MW. ECG of the Month. *J Am Vet Med Assoc* 2008;233:44–46.
6. Kastor JA, Goldreyer BN, Josephson ME, et al. Electrophysiologic characteristics of Ebstein's anomaly of the tricuspid valve. *Circulation* 1975;52:987–995.
7. Kistler PM, Roberts-Thompson KC, Haqqani HM, et al. P-wave morphology in focal atrial tachycardia: development of an algorithm to predict the anatomic site of origin. *J Am Coll Cardiol* 2006;48:1010–1017.



## PARTNER SPOTLIGHT

### New Weight Reduction Program for Dogs from Hill's Pet Nutrition Inc.

Hill's Pet Nutrition Inc. has launched the Hill's® Prescription Diet® Therapeutic Weight Reduction Program, a veterinary exclusive product designed for owners of overweight, obese or obese prone dogs. The program starter kit, designed to improve client compliance, contains pre-measured clinically proven Hill's® Prescription Diet® r/d® Canine Weight Loss-Low Calorie Dry brand pet food, low-calorie biscuits and a program guide. The guide contains helpful weight loss information including the veterinary health care team feeding recommendation, instructions and tips for successful weight loss.

This program serves as an all-inclusive solution for weight loss in dogs and utilizes the body fat index (BFI) scoring system, the next evolution of the body condition score (BCS). The new BFI scale emphasizes body fat percentage over the BCS to determine the severity of a pet's weight problem. The health care team can then determine the appropriate food dose for successful weight loss to help reduce the risks associated with high body fat.

The Therapeutic Weight Reduction Program targets dogs with a BFI of greater than or equal to 30, and it is available in two sizes: small breed with up to a 5-week supply as well as medium to large breed with up to a 4-week supply of pre-measured pet food and biscuits. Replacement cartons to refill both the meals and biscuits storage box are also available.

Pet owner online support can be found by visiting PetFit.com, and home delivery is available. To find out more about home delivery, veterinary healthcare team members are encouraged to contact their Hill's representative.



- Advertorial -