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ECG of the Month

A 10-year-old 640-kg show jumping Selle Français mare was presented for episodes of exercise intolerance and weakness of 5 months' duration. The mare was referred after a new arrhythmia was auscultated by the referring veterinarian.

On examination, the mare was bright and alert and had a normal body condition score (3/5). Heart rate was low (17 beats/min), and cardiac auscultation revealed a grade 3/6 left- and right-sided holosystolic murmur associated with an irregularly irregular arrhythmia. No signs of congestive heart failure such as edema or jugular distension were detected. Mucous membranes were pink and moist with a capillary refill time < 2 seconds. Respiratory rate was 36 breaths/min with normal bronchovesicular sounds during rebreathing examination. Rectal temperature was 38.1 °C. Gastrointestinal sounds and digital pulses were considered normal.

In horses without any obvious lameness, exercise intolerance is most often secondary to a cardiac, respiratory, or muscular disorder. In this case, the bradyarrhythmia and cardiac murmur oriented more toward cardiac disease. Therefore, a complete cardiac evaluation was recommended along with an exercise tolerance test to exclude other disorders.

During the exercise tolerance test (20 minutes of lunging at a trot and a gallop), the mare appeared abnormally tired and had a prolonged recovery time. Creatinine kinase concentration was within reference limits before and 1.5 hours after exercise (88 and 51 U/L, respectively; reference range, 10 to 350 U/L), and maximum lactate concentration was 3.4 mmol/L (reference range, < 4 mmol/L). No abnormal respiratory noise was heard during exercise. Thoracic radiography revealed a mild bronchial pattern, and bronchoalveolar lavage revealed neutrophilic inflammation (68% neutrophils; reference range, < 5% neutrophils) suggestive of mild asthma. ECG tracings were obtained while the horse was exercising and at rest, echocardiography was performed, and troponin-I concentration was measured.

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ECG Interpretation

A base-apex ECG tracing recorded with the horse at rest revealed advanced second-degree atrioventricular (AV) block **(Figure 1)**, with an AV conduction

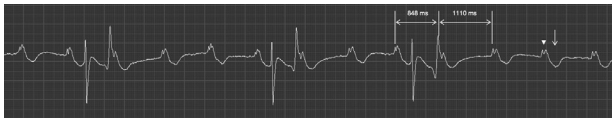

Figure 1—Base-apex ECG tracing from a 10-year-old Selle Français mare with episodes of exercise intolerance and weakness of 5 months' duration. Notice the nonconducted P waves characteristic of advanced second-degree atrioventricular (AV) block (defined as ≥ 3 blocked P waves in succession). The mean sinus rate is 64 beats/min, and the ventricular rate is 17 beats/min. Ventriculophasic sinus arrhythmia can be seen, with shorter P-P intervals when a QRS complex is included (double-headed arrows). Large Ta waves (arrow) follow P waves (arrowhead). Paper speed = 25 mm/s; 2 cm = 1 mV.

ratio ranging from 2:1 to 6:1. The atrial rate was high (64 beats/min) but mainly regular with evidence of ventriculophasic sinus arrhythmia. Mean ventricular rate was 17 beats/min.

Mean PR interval was 330 milliseconds, QRS complex duration was 140 milliseconds, and the $QT_{corrected}$ interval was 580 milliseconds (Fridericia correction method), which were all within reference limits.[1] The PR intervals were stable, but the blockage could not be characterized as Mobitz type I or II because it was not possible to observe 2 consecutive P waves that were conducted.

Echocardiography revealed mild aortic regurgitation, with mild left ventricular distension compensated by increased shortening fraction (56%). The murmur was an ejection flow murmur. Results of hematologic and serum biochemical testing, including measurement of serum electrolyte and troponin-I concentrations, were all within reference limits. Results of serologic testing for *Borrelia burgdorferi* were negative.

Additional ECG tracings were obtained with the horse at a trot **(Figure 2)** and a canter. Mean ventricular rate was 54 beats/min at a trot and 70 beats/min at a canter. Despite artifacts associated with exercise testing, some P waves could still be visualized owing to the low ventricular rate. Atrial rate was determined to be between 164 and 191 beats/min at a trot and between 254 and 286 beats/min at a canter. The sinus rate was inappropriately high

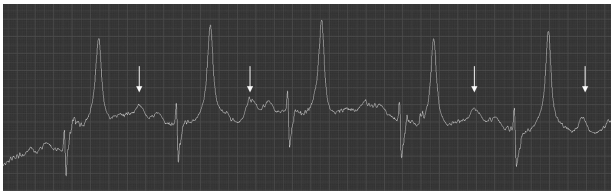

Figure 2—Base-apex ECG tracing obtained while the mare was trotting. Artifacts associated with the horse's movements make interpretation difficult, but second-degree AV block can be appreciated, with multiple non-conducted P waves (arrows). The sinus rate ranged from 164 to 191 beats/min, and the mean ventricular rate was 54 beats/min. Paper speed = 50 mm/s; 2 cm = 1 mV.

(reference range,[2] 80 to 100 beats/min at a trot and 100 to 140 beats/min at a canter), and the ventricular rate was inappropriately low. Increased heart rate variability could be seen on a tachogram, which represents instantaneous heart rate, and Poincaré plots, for which each point represents the R-R interval (x-coordinate; **Figure 3**) in relation to the following R-R

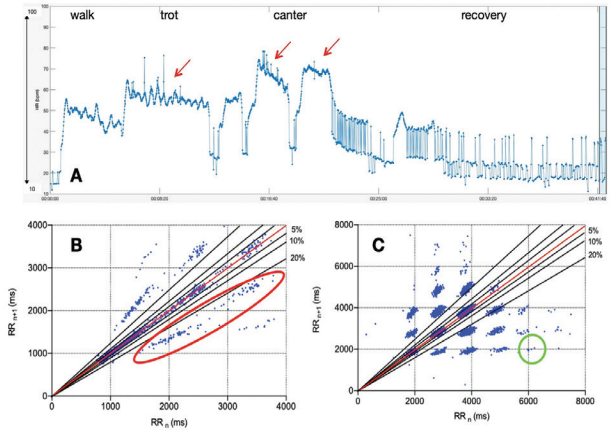

Figure 3—Tachogram (A) and Poincaré plots obtained during exercise (B) and while the mare was at rest (C). In the tachogram, the heart rate is not consistent with the level of exercise (54 beats/min at a trot and 70 beats/min at a canter), and second-degree AV block is obvious during recovery. High heart rate variability is evident (arrows), likely due to the AV block. The Poincaré plots show mainly 2:1 AV conduction (red circle) during exercise and up to 5:1 AV conduction at rest (green circle). The line of identity (red line) represents a perfectly regular rhythm with each R-R interval approximately equal to the following R-R interval. The black lines indicate landmarks for heart rate variability.

interval (y-coordinate; Figure 3). Poincaré plots are visual representations of heart rate variability that are convenient for interpretation of ECG tracings obtained during exercise (when artifacts are numerous) or overnight (when recordings are very long). In horses, heart rate variability should be < 6% during exercise[3] and < 20% at rest.[4] Second-degree AV block can be seen as groups of points on each side of the line of identity, with heart rate variability higher than accepted thresholds.

Persistent advanced second-degree AV block during exercise was diagnosed. The consequent impaired cardiac output could explain the exercise intolerance and episodes of weakness in this mare.

The mare was discharged with a prescription for dexamethasone (0.05 mg/kg, IM, q 24 h) and directions to restrict exercise for 1 month and return for a recheck evaluation. Only adults aware of the mare's condition were allowed to manipulate the mare owing to the high risk of collapse. One month later, the mare presented with episodes of collapse at rest. At that time, ECG revealed third-degree AV block. The mare was immediately sent to a referral center where implantation of a single-chamber VVI-CLS pacemaker was scheduled. However, 3 days after the mare's arrival and while waiting for the procedure, the mare developed a fever and suddenly died from asystole and ventricular fibrillation. A necropsy was performed and did not show any abnormalities, including in the cardiac tissue. Results of a PCR assay for *B burgdorferi* antigen were negative.

Discussion

Advanced (or high-grade) second-degree AV block is rare in horses, and only a few case reports are available.[5–11] Advanced second-degree AV block is defined as ≥ 3 blocked P waves in succession in horses[12] and ≥ 2 blocked P waves in succession in humans.[13] Reported causes in horses include electrolyte imbalance, digitalis toxicosis, AV nodal disease (inflammatory or degenerative),[14] borreliosis,[15] and idiopathic.[16] In humans, coronary artery disease, autoimmune disorders, infectious or hypersensitivity myocarditis, infiltrative processes, hypervagotony, and degenerative scleroatrophy of the AV junctional tissue are reported causes.[17] In this horse, PR intervals were stable, suggesting an infranodal block.[18] On the contrary, if PR intervals are different before and after AV blocks, the block can also be in the His-Purkinje system.

Ventriculophasic sinus arrhythmia was observed in this horse and is commonly noted with second- and third-degree AV blocks. Ventricular contraction increases sinus node blood supply, causing an earlier sinus node discharge (positive chronotropic effect). Also, a vagal reflex caused by ventricular ejection and increased arterial pressure can slow firing of the sinus node and lengthen the following P-P interval without a QRS complex (negative chronotropic effect).[19]

Advanced second-degree AV block may resolve on its own in some horses, but evolution to third-degree AV block is likely in most cases, and permanent pacemaker implantation is indicated at the time of diagnosis, especially if blockage is still present during exercise or after administration of a vagolytic drug.[15] In this horse, an exercise tolerance test was performed instead to evaluate the respiratory and muscular systems as potential causes of exercise intolerance, and atropine can cause persistent ileus and colic in horses. In human medicine, temporary transvenous pacing can be recommended in patients with second-degree AV block associated with symptoms or hemodynamic compromise that is refractory to antibradycardic medical treat-

ment.[20] Pacemakers can be implanted successfully in horses[21]; unfortunately, the COVID-19 pandemic caused the procedure to be delayed.

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