A 5-year-old Suffolk ram was admitted to a veterinary teaching hospital for chronic weight loss and a 4-day history of anorexia, lethargy, bruxism, and diarrhea. The ram had been treated with anthelminthics and antibiotics, with no clinical signs of improvement.

On physical examination, the ram was in poor body condition (body condition score, 2/5), and a doughy mass was palpable in the ventral portion of the abdomen on the right. Rumen contractions were not detected, and an irregularly irregular cardiac rhythm was auscultated. No heart murmurs or pulse deficits were detected. Rumen fluid analysis revealed low protozoal activity and a rumen chloride concentration within reference range. Complete blood count results were consistent with a stress leukogram. Serum biochemical analysis revealed hyponatremia, hypokalemia, hypocalcemia, hypomagnesemia, and metabolic acidosis.

Alligator electrodes were attached to the ram's skin behind the elbow joints on both forelimbs and on the left hind limb, and an ECG was recorded. Electrocardiography revealed atrial fibrillation. No gross morphologic abnormalities were detected during cardiac ultrasonography. Although rumen chloride concentration was within reference range, a motility disorder of the forestomach was suspected, with resulting abnormalities in serum electrolyte concentrations and cardiac rhythm.

Initially, treatment was supportive and included correction of serum electrolyte abnormalities with IV administration of polyionic fluids, administration of fresh rumen liquor from a donor cow via an orogastric tube (transfaunation or reinoculation), and IM administration of erythromycin as a prokinetic agent. The owner did not approve exploratory surgery for diagnostic purposes.

Despite correction of serum electrolyte concentrations, the ram remained anorectic, obtunded, and in atrial fibrillation. On day 5, it was decided to directly treat atrial fibrillation by means of electrical cardioversion. The ram was anesthetized (2 mg of ketamine/kg [0.91 mg/lb] of body weight, IV; 0.5 mg of diazepam/kg [0.23 mg/lb], IV) prior to electrical cardioversion. A cardiosynchronous defibrillator was used. Paddles were placed over the right heart base (behind the triceps muscles) and the left cardiac apex (close to the sternum). Immediately prior to cardioversion, the ram's heart rate was 100 to 115 beats/min (Fig 1). To our knowledge, there are no published values recommended for cardioversion in sheep. Given the clinical experience of one of the authors (ECO) and the size of the ram, 100 J was considered a conservative amount of energy at which to attempt cardiover-
There was no response at this amount of energy, and in further attempts the amount was increased stepwise. Cardiac rhythm did not convert to normal sinus rhythm at 200 or 300 J, but conversion was achieved at 360 J, the highest possible setting for the available equipment (Fig 2).

**ECG Interpretation**

In the first ECG, the ventricular rate is 100 to 115 beats/min, R-R intervals are irregularly irregular and vary in size, P waves are not observable, and fibrillation f waves are evident, all of which are indicative of atrial fibrillation (Fig 1). The automated external defibrillator sensed each R wave. In the second ECG, the ventricular rate is 92 beats/min, and the R-R intervals are equal (Fig 2). There is a P wave for every QRS complex and a QRS complex for every P wave. The QRS complexes are similar to each other in size and shape. The P wave is discernible and diphasic. Although diphasic P waves are found in dogs with large atria and are occasionally seen in clinically normal cattle, the authors are not aware of any reports of diphasic P waves in sheep. Subsequent ECG indicated maintenance of normal sinus rhythm with a heart rate of 72 to 85 beats/min.

Despite successful conversion, the ram remained obtunded and anorectic. Because of a poor long-term prognosis and lack of clinical improvement, euthanasia was elected on day 15. Necropsy revealed a distended abomasum full of firm dry ingesta. The abomasum had multiple small ulcers, and the myenteric plexus were disrupted. These findings are consistent with abomasal emptying defect (AED). The right auricle of the heart was dilated, and there was a loss of muscle tone in the right ventricle.

**Discussion**

Atrial fibrillation has classically been described as a condition in which atrial and ventricular rates are rapid and irregularly irregular, although some authors have found that atrial fibrillation does have a complex spatiotemporal organization. On an ECG, atrial fibrillation typically has f waves that replace normally found sinus P waves. The QRS complex configuration can vary from normal in appearance to wide and bizarre. Atrial fibrillation is caused by disorganized atrial depolarization and causes loss of effective atrial contraction.

Atrial fibrillation is rarely described in sheep outside experimental paradigms. In other ruminant species, differential diagnoses for atrial fibrillation can be divided into primary and secondary causes. Primary cardiac causes include myocardial disease, atrioventricular valve regurgitation, and ventricular failure. Secondary causes can involve the gastrointestinal tract (electrolyte and acid-base imbalances), the nervous system (autonomic nervous system imbalance), drug-induced, and idiopathic causes. In cattle, the most common causes of atrial fibrillation are electrolyte and acid-base imbalances caused by gastrointestinal tract disease. Arrhythmias associated with alkalemia are thought to result from the development of hypokalemia.

Abomasal emptying defect is a syndrome primarily affecting Suffolk sheep between 2 and 5 years of age, although it has been described for other breeds. The cause and pathophysiologic changes of AED are poorly understood, and various treatment protocols have been unsuccessful.

In cattle, abomasal emptying disorders are characterized by hypochloremia, hypokalemia, and metabolic acidosis. Although some affected sheep have these electrolyte abnormalities, most have serum electrolyte concentrations within reference ranges, because in sheep affected with AED, the pylorus remains patent. This allows some ingesta to pass into the small intestine, where chloride and hydrogen are absorbed. Tachycardia has been described for sheep with AED.

Atrial fibrillation resulting from primary cardiac disease is seldom observed in ruminants. However, it is common, relative to primary disease, for ruminants to have atrial fibrillation secondary to gastrointestinal tract disease. If a primary gastrointestinal tract disease is successfully treated and electrolyte imbalances are corrected and maintained for 5 to 7 days, 40 to 50% of cattle with atrial fibrillation permanently self-convert to a normal sinus rhythm. The prognosis for successful conversion decreases over time. The chronicity and lack of clinical improvement following treatment suggests a serious underlying condition. In
our ram, signalment as well as physical and necropsy findings were consistent with a diagnosis of primary gastrointestinal tract disease, or AED, with secondary cardiac disease. To our knowledge, there are no prior reports of atrial fibrillation in sheep in association with AED.

Pharmacologic cardioversion of atrial fibrillation was considered for our ram, using IV administration of quinidine. However, this method is time consuming, and quinidine toxicity carries a substantial risk of adverse gastrointestinal tract signs.

Conversion with electrical defibrillation is commonly performed in human medicine. Cardioversion is the discharge of electrical energy to the heart in synchrony with the depolarization of the ventricles (ie, during the R wave). Automated external defibrillators sense R waves and will fire during the next R wave after discharge (Fig 1). Synchronization with the R wave prevents accidental triggering of ventricular fibrillation. Depolarization of the atria allows organized electrical activity to resume.

The success of electrical defibrillation largely depends on the duration of the condition; the longer the animal has been in atrial fibrillation the less likely it is to successfully convert or remain converted. Other reasons for failure to convert are heart failure, irreversible changes to the myocardium, unresolved gastrointestinal tract disease, and persistent electrolyte imbalances. In human medicine, other common treatment options include the combination of cardioversion and antiarrhythmic drugs or not converting the atrial fibrillation but instead controlling the ventricular rate.

Electrical defibrillation is economic, straightforward, and rapid. It is a treatment modality with potential, but it also can have serious complications. These include morphologic and functional cardiac damage following the use of high-energy shocks. Asystole and cardiac arrest can occur if cardioversion is not delivered during the R wave. When ventricular arrhythmias develop, they are usually related to improper synchronization, repeated use of high amounts of energy, hypokalemia, or severe underlying heart disease. It is important to evaluate the patient's condition and history when considering the use of cardioversion as a treatment.

References


Contributed by Anneke Moresco, DVM, MS; J. David Haworth, DVM, PhD; E. Christopher Orton, DVM, PhD, DACVS; George M. Barrington, DVM, PhD, DACVIM, Department of Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, CO 80523. Dr. Moresco’s present address is the Carnivore Preservation Trust, 1940 Hanks Chapel Rd, Pittsboro, NC 27312. Dr. Haworth’s present address is Pfizer Global Research and Development, Groton Laboratories, Mail Drop 8200-45, Groton, CT 06340. Dr. Barrington’s present address is the Department of Veterinary Clinical Sciences, College of Veterinary Medicine, Washington State University, Pullman, WA 99164-7060.