History

A 5-year-old, captive, intact male bearded dragon (*Pogona vitticeps*), with a 5-day history of anorexia and constipation, was presented for peracute onset of obtundation, regurgitation, and black discoloration of the ventral chin and neck. The animal was a privately owned pet, with no prior medical history of disease. Although the diet and husbandry of the patient was, in general, acceptable, the lizard was maintained in the owner's basement. The location of the bearded dragon's primary enclosure did not provide much light or ventilation. Moreover, the lizard was allowed to roam the basement freely for extended periods of time.

On physical examination, the lizard weighed 424 g and was in fair body condition (body condition score = 2/5), but was severely dehydrated and unresponsive to stimuli. The patient was very weak and unable to hold up its head. The ventral chin and neck were densely black, and both eyes were sunken. There was a large amount of mucoid regurgitant in the patient's oral cavity. An irregular heart rhythm (heart rate = 72 beats per minute) was auscultated via Doppler and 2 bilateral fat pads were palpable in the abdomen. The lizard never moved and its body was rigid both during the examination and at rest.

Blood was collected from the ventral tail vein and submitted for a serum biochemistry analysis and a complete blood count. The serum biochemistry test results revealed hyperkalemia (11.6 mEq/L; reference range: 1 to 6.5 [mean = 3.6] mEq/L), hypophosphatemia (0.6 mg/dL; reference range: 2.7 to 15.1 [mean = 5.7] mg/dL), and a marked hyperglycemia (500 mg/dL; reference range: 139 to 291 [mean = 210] mg/dL).[1] All complete blood count results were within normal range. Whole-body orthogonal radiographs were performed, and findings revealed no abnormalities.

Supportive care included the concurrent subcutaneous administration of 0.9% sodium chloride (20 mL/kg) with B vitamin complex (Super B Complex, Vedco, Lenexa, KS USA) and enrofloxacin (15 mg/kg Baytril; Bayer HealthCare LLC, Shawnee Mission, KS USA). The lizard was then placed into an incubator at 31°C (88°F). The subcutaneous treatments were repeated later that night. On physical examination the following morning, it was noted that the lizard had not moved all night. The patient was able to make slight lateral movements with its head, but was still obtunded, and the black discoloration of the ventral chin and neck was unchanged. There was no evidence of regurgitation or vomiting overnight, and there was no regurgitant present in the oral cavity. There was no arrhythmia auscultated by Doppler that morning, and the heart rate was 54 beats per minute. Digital palpation of the abdomen and cloaca during the examination resulted in voiding of the bladder and a release of a large amount of feces from the cloaca. The subcutaneous treatments as previously described were repeated for a third time, and the lizard was returned to its incubator.

Despite the slight improvement of some of the clinical signs overnight, the lizard died that afternoon. Gross necropsy was performed immediately after death and revealed some ingesta and 3 well-preserved segments of a firefly present in the stomach. There were no other abnormalities noted on gross necropsy. All tissues, including the brain, heart, and abdominal fat pads, were placed in 10% buffered formalin and submitted for histopathology. No histopathologic abnormalities were observed in any of the tissues.

At this time, please evaluate the history, clinical presentation, and the physical examination, complete blood count, serum biochemistries, necropsy, and histopathologic findings. Based on this information, please develop a differential diagnoses for the cause of the bearded dragon's death.

DIAGNOSIS

Owing to the acute nature of the disease and lack of any significant hematologic, postmortem, or histopathologic findings, toxicosis was strongly suspected. With the findings of severe hyperkalemia, an obvious color change in the ventral chin, arrhythmia, and a firefly (*Photinus* sp.) in the stomach, a diagnosis of firefly toxicosis is compatible with the clinical signs and acute death observed in this animal.

Fireflies of the genus *Photinus* (Fig. 1) are poisonous, and the ingestion of even one of these fireflies may be lethal to an adult bearded dragon.[2] Fireflies contain cardioactive steroids called lucibufagins. Cardioactive steroids are classified as a cardenolide (with a 5-membered lactone ring) or a bufadienolide (with a 6-membered lactone ring).[3] Most cardenolides are derived from plants (i.e., digitoxin and digoxin are extracted from the *Digitalis* genus [foxglove]). In contrast, most bufadienolides (e.g., bufalin), including those commonly found in toads, are derived from mammals and amphibians.[3] The chemical structures of the 5 major lucibufagins found in *Photinus pyralis* are characterized as esters (5, 6, 7, 11, and 12) of 12-oxo-2β,5β, 11α-trihydroxybufalin, thereby classifying all as bufadienolides. These steroids are the first insect-derived bufadienolides to be fully described.[4] It is important to note that bufadienolides are 5 times more lethal than cardenolides with respect to human intoxications.[3]

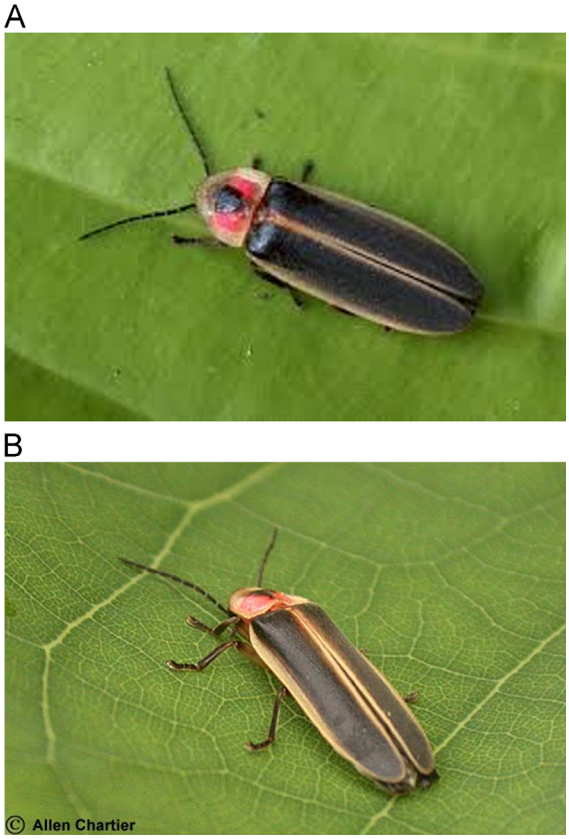

FIGURE 1. Photographs of fireflies (*Photinus pyralis*). (Chartier A: Photographs, amazilia.net. Accessed September 1, 2013.)

The lucibufagins protect *Photinus* against predation by most species.[2,4,5] Spiders and most birds are orally deterred by lucibufagins, and birds of the genus *Hylocichla*, which includes the thrushes, have shown reluctance to attack *Photinus*.[2,4,5] In the exceptional case where a *Hylocichla* was noted to ingest a *Photinus*, the bird reacted in short order by regurgitating it.[2,5] Other sources have shown that there are some predators such as goatsuckers (Caprimulgidae), potoos (Nyctibiidae), spiders of the families Araneidae and Lycosidae, and certain anoles (Iguanidae) and frogs that can eat firefly prey, at least during certain periods of the year.[6]

Clinical signs associated with ingestion of a firefly in 2 bearded dragons in which toxicity and death had been reported included gaping and head shaking, color changes from tan to black, dyspnea, and rapid death within several hours of ingestion. No gross internal lesions were noted at necropsy.[2]

DISCUSSION

Bufodienolides and cardenolides are cardiac glycosides that cause an increase in intracellular calcium by inhibition of the sodium-potassium-ATPase activity in cardiac muscle. Buildup of calcium inside the myocardial cell and potassium outside of the cell result in stronger myocardial contractions and a decreased heart rate, respectively. The cardioactive steroids have both been shown to induce nausea and emesis at low concentrations; however, they can also be lethal at remarkably low dosages (ouabain: LD_{50}, intravenous, cat = 0.11 mg/kg; bufalin: LD_{50}, intravenous, cat = 0.14 mg/kg).[2] A case report describing 2 bearded dragon deaths subsequent to firefly ingestion suggests that if lucibufagins are comparably toxic and if lizards are as sensitive as cats, a systemic dose of 10 to 20 μg lucibufagin—less than half the amount in a single *Photinus*—could be lethal to a 100-g bearded dragon.[2] The same report also notes that pharmacological tests performed by Schering-Plough Corporation established that lucibufagins induced ventricular arrhythmia in dogs when administered

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