Title: A Home-Made Defibrillator Revives a Comatose Captive Bearded Dragon (*Pogona vitticeps*)

Christopher G. Marinescu, BS[1], Justin R. Perrault, PhD[1,2], Stephen J. Kuehl, BE[3], Deby L. Cassill, PhD[1]

1. University of South Florida Saint Petersburg, Department of Biological Sciences, 140 7th Avenue South, Saint Petersburg, Florida 33701
2. Loggerhead Marinelife Center, 14200 U.S. Highway 1, Juno Beach, Florida 33408
3. Pierce Manufacturing, Incorporated, 1512 38th Avenue East, Bradenton, Florida 34208

E-mail addresses: cmarinescu@usfsp.edu (C.G. Marinescu), jperrault@marinelife.org (J.R. Perrault), skuehl@piercemfg.com (S.J. Kuehl), cassill@usfsp.edu (D.L. Cassill)

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Abstract

Reptiles present interesting veterinary cases in relation to drowning, as the majority of the animals in this group are hypoxia-tolerant. These organisms can survive prolonged periods of little to no oxygen without suffering lasting physiological effects. In the case presented here, a captive inland bearded dragon (*Pogona vitticeps*) fell into a residential pool and was submerged for >10 minutes. Upon rescue, the animal was unresponsive. In an effort to resuscitate the animal, three counter shocks were delivered using aluminum wire and an electrical outlet. This successfully revived the animal with no lasting physiologic effects observed. The case presented here represents a "*don't try this at home*" scenario and also provides insight into resuscitation and recovery of reptiles. Although there are a number of unknowns and estimated parameters, we think this case study provides valuable information on the possibility of designing defibrillators for animals of all sizes.

INTRODUCTION

The dive response is a well-known phenomenon that occurs in reptiles, birds, and mammals and is characterized by apnea, a decrease in heart rate, and constriction of peripheral blood vessels (Davis, Polasek, Watson, Fuson, Williams, and Kanatous 263). Periods of breath-hold during the dive response lead to hypoxic conditions inside the body. The dive response is an evolutionary adaptation for numerous aquatic ectotherms (*e.g.*, amphibians, freshwater and marine turtles, aquatic snakes) that experience low-oxygen environments (Belkin 492). Although a number of lacertids are known to survive anoxic environments for over 1 h (Belkin 492), little information is available regarding the dive response or hypoxia tolerance among terrestrial lizards (Bickler, Buck 150).

While hypoxia tolerance is widespread throughout the Class Reptilia, these organisms can still drown if deprived of oxygen for prolonged periods. Drowning for the sake of this case study describes a comatose, unresponsive organism and does not refer to death by cardiac arrest. If a reptile drowns, cardiopulmonary-cerebral resuscitation (CPCR) and defibrillation can be performed; yet, this type of rehabilitation has been rarely documented in the literature, especially for exotics (Shoop 5; Balazs 79; Stabenau, Moon, and Heming 3–5; Costello 132–141; Martinez-Jimenez and Hernandez-Divers 557–585; Darvall and Smith 694). In the following section, we describe in detail the delivery of CPCR and electrical defibrillation to revive a comatose inland bearded dragon (*Pogona vitticeps*) accidentally drowned in a swimming pool.

CASE HISTORY

On September 28, 2015, a 3-year old male (mass = 350 g; total length = 40.6 cm) bearded dragon escaped from his outdoor enclosure and was found unresponsive at the bottom of a 1.8 m deep, ~21°C (~70°F) unheated pool in Largo, Florida. Christopher G. Marinescu, the owner of the bearded dragon and first author of this manuscript, estimated that the animal had been submerged for >10 minutes. The bearded dragon was removed from the pool, placed in a supine position, and mouth-to-mouth CPCR was performed by the owner at his residence for 10 minutes. The lizard experienced “wet drowning” as water was expelled from the lungs after CPCR was administered. No published protocols were followed for CPCR; however, CPCR performed by the owner consisted of 3 chest compressions (~1 s apart) using three fingers followed by one rescue breath (~1–2 s in length) for successive cycles (2–6 breaths/min are recommended: Costello 140; Martinez-Jiminez and Hernandez-Divers 576). CPCR did not revive the comatose animal, but did successfully remove water from the lungs.

In a continued effort to revive the animal, a make-shift defibrillator was fashioned using OOK® 0.08 cm aluminum hobby wire, rubber-handled pliers, and an electrical outlet (~110–120 V). A loop was formed at one end of the wire, which was placed around the animal (**Fig. 1**). The wire was inserted into the electrical outlet on and off for a total of 3 repetitions or counter shocks. In between each counter shock, CPCR was administered using three chest compressions followed by a short rescue breath (~1–2 s). Each shock produced muscle contraction in the animal. After the third shock, the animal’s color returned, he began breathing, and his eyes opened.

Immediately thereafter, the lizard was taken to the Avian and Animal Hospital of Largo, Florida where Nichole L. Zellner, DVM, performed a thorough examination of the animal. Based on her findings, she prescribed meloxicam (Metacam® 1.5 mg/mL, Boehringer Ingelheim Vetmedica, Inc., St. Joseph, Missouri 64506 USA): 0.2 mg/kg q24h for 3 d PO for inflammation/pain and sulfamethoxazole/trimethoprim (Sulfamethoxazole and Trimethoprim Oral Suspension USP 200 mg/40 mg per 5 ml, Hi-Tech Pharmacal Co., Inc. Amityville, New

York 11701, USA): 30 mg/kg b.i.d. for 10 d PO for infection. At the time of this writing, 18 months after the event, the lizard is alive and healthy with no observable changes in physical ability or behavior.

DISCUSSION

The inland bearded dragon (*Pogona vitticeps*) is native to the hot, dry, and sometimes coastal regions of central Australia. These lizards are semi-arboreal and spend time basking in sandy or rocky areas. Bearded dragons are ectotherms that modify their body temperature by moving from sunny to shady areas or burrows during the hottest part of the day. They are moderately large lizards, and thus, are popular in the global pet industry (Doneley 1607–1608). We speculate that the inland bearded dragon in this case study was not dead when recovered from the bottom of the pool, but instead comatose and unresponsive as a result of three physiologic conditions: prolonged hypoxia, hypothermia, and exhaustion.

The first threat to this animal was hypoxia. In 13 species of lizards from five families (Anguidae, Gekkonidae, Iguanidae, Scincidae, Teiidae), hypoxia tolerance was observed through nitrogen exposure for 20–79 minutes with no differences between aquatic and terrestrial species (Belkin 492). In another study, a desert-dwelling species (lesser earless lizards, *Holbrookia maculata*) survived for ~5 h in a pure nitrogen (anoxic) environment, but could only remain forcibly submerged for 2–15 min (mean = 7.9 min) before drowning (Meyer 166). Struggling during forced submergence has been shown to quickly deplete oxygen stores (Caillouet 1). During forced submergence, the heart rate of rattlesnakes (*Crotalus viridis*) dropped by just 4%, while the heart rate of northern water snakes (*Nerodia sipedon*) dropped by 36% (Ferguson and Thornton 185). Therefore, the dive response in terrestrial reptiles is less successful in reducing oxygen usage during forced submergence in comparison to aquatic species (Ferguson and

Thornton 185–187; Davis, Polasek, Watson, Fuson, Williams, and Kanatous 267). The dive response during forced submergence serves to protect the organism from immediate asphyxiation, but can cause severe disruption of homeostasis in comparison to normal breath-holds for semi-aquatic or aquatic species (Caillouet 1). We speculate that the bearded dragon in our case study struggled before sinking, depleting much of its available oxygen stores and disrupting its physiologic homeostasis.

Hypothermia was another potential health issue for this ectothermic lizard. Terrestrial lizards are capable of efficient swimming; however, they generally avoid contact with deeper, colder bodies of water (Darvall and Smith 694). Body temperature equilibration with the surrounding water in reptiles can take less than five minutes. The optimal body temperature of *P. vitticeps* is ~33–37°C (~91–99°F) (Frappel and Daniels 992–993; Melville and Schulte 662), while the temperature of the pool was ~21°C (~70°F). Thus, this bearded dragon likely suffered hypothermia (and cold-stunning) as well as hypoxia.

Exhaustion was a third threat. When swimming, lizards inflate their lungs and use their tails to produce lateral undulations. This pattern of locomotion is similar to their pattern of movement on land (Darvall and Smith 694). Because the anatomy of most lizards places constraints on simultaneous movement and replenishment of oxygen stores, this animal probably became exhausted after ≤ 2 min of movement (Pough, Janis, and Heiser 255–256). Bearded dragons have high oxygen consumption and respiratory rates relative to other agamid lizards (Frappel and Daniels 995). It is unknown how long the lizard in this case study was attempting to swim before becoming submerged, but it is likely that the animal suffered the near drowning event quickly because of the organism’s limited oxygen stores, hypothermia, and exhaustion.

In general, reptiles have a greater capacity for anaerobic metabolism in comparison to endotherms (Bennett and Ruben 650) and resuscitation can be achieved after suspected cardiac arrest or extended periods without oxygen (Darvall and Smith 694). For example, in marine turtles where drowning and death have been suspected, it is often found that these organisms are comatose and can recover after a period of days to weeks (Shoop, Ruckdeschel, and Wolke 85). Electrical defibrillation is rarely used on small exotics because there is a large potential for adverse effects. Moreover, side effects are unknown (Stabenau, Moon, and Heming 3–5; Costello 136). In 1981, a leatherback sea turtle (*Dermochelys coriacea*) went into respiratory collapse after being forcibly submerged in a pound net. The animal was unresponsive and electrodes were placed into the pectoral musculature and attached with automotive jumper cables to a car battery (~12 V). This animal revived and was released (Shoop 5). This suggests that in worst-case scenarios, electric shock therapy can be successfully utilized with exotics. However, problems can arise with human defibrillators on smaller exotics as their paddle sizes are too large. Additionally, defibrillators often do not have energy levels low enough to administer a safe voltage to the animal (Costello 136).

We estimated the specific energy in J/kg of the “defibrillation” in our case study and compared it to what is recommended in the literature for reptiles (Costello 135–136). Specific energy can be described by the following equation derived from Ohm’s law and the definition of electrical power:

$$e = \frac{V^2 t}{Rm}$$

where e represents specific energy (J/kg), V represents voltage (V), t represents time of contact (s), R represents electrical resistance of skin (Ω), and m represents the mass of the animal (kg). The outlet used was 110–120 V AC rms at 60 Hz. The time that the animal was energized was assumed to be 0.25 s based average human reaction time to insert and remove the wire from the outlet. Since a value for electrical resistance of reptile skin does not exist in the literature, we estimated a range to determine a maximum and minimum value for the specific energy delivered to the specimen. We assumed the maximum resistance value of reptile skin to be similar to a dry, calloused human hand (100,000 Ω) due to the thick outer layer of dead cells in the stratum corneum (Fish and Geddes 408). Using the equation above, we estimate that the minimum output of the electrical socket to be ~0.1 J/kg, which falls below the recommended values for external defibrillation in a 200–500 g reptile (1 J/kg is recommended: Costello 135). Wet skin may drop the human body's resistance to as low as 1,000 Ω (USDHHS 7) and we used this as our minimum resistance to estimate that the maximum specific energy delivered was ~10 J/kg.

If electric shock therapy is warranted, three successive counter shocks are recommended, with the initial shock ranging from 1–4 J/kg depending on the weight of the animal. If this range is unsuccessful, the shock energy can be increased to 5–10 J/kg (Costello 136). In our case study, the wetness of the bearded dragon's skin likely countered the thickness of its skin. Thus, the low estimated ~0.1 J/kg shock energy used to revive the bearded dragon was enhanced by water and, at the same time, the thick, scaly nature of the bearded dragon's skin likely prevented a dangerous level of current. Based on our estimations, less energy/voltage may be required than is recommended (Costello 135–136) to adequately resuscitate a comatose reptile.

In summary, we have described "*don't try this at home*" revival methods; yet, we commend the owner for his first-responder resourcefulness in addition to seeking appropriate veterinary aftercare. It is noteworthy that no physical or behavioral abnormalities have been noted in the bearded dragon since the event. Certainly, this case makes for an interesting story, but it also provides insight into resuscitation and recovery of reptiles. Although there are a number of unknowns and a number of estimated parameters, we think this case study provides valuable information on the possibility of designing defibrillators for animals of all sizes.

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Figure Legend

Figure 1. Defibrillation setup showing the pliers, wire (notice the loop around the animal) and the bearded dragon.