GASTROINTESTINAL STUDIES IN THE GREEN IGUANA: TECHNIQUE AND REFERENCE VALUES

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Five healthy green iguana (*Iguana iguana*) were used to determine appropriate technique and normal transit times for gastrointestinal contrast studies and to describe normal radiographic anatomy. The animals were maintained at 27–29°C. There was rapid transit through a U shaped stomach, with a median gastric emptying time of 8 h, and median small intestinal transit and small intestine emptying times of 4 h and 16 h respectively. Median large colon transit and emptying times were 15 h and 66 h. Maintaining the iguana at a reduced ambient temperature increased all of these times. The vaso-vagal response or mechanical methods were adequate for restraint. A 25ml/kg dose of a 25% w/v suspension of barium administered by stomach tube gave the best results. Lateral and ventrodorsal projections of the abdomen should be made immediately following the administration of the barium and at 1-hour intervals for the first 6 h and at 12-hour intervals thereafter until barium can be identified in the distal descending small colon. *Veterinary Radiology & Ultrasound, Vol. 42, No. 6, 2001, pp 515–520.*

Key words: green iguana, Iguana iguana, reptile, contrast study, gastrointestinal.

Introduction

THE GREEN IGUANA (*Iguana iguana*) is one of the more common reptilian pets seen in small animal practice. These animals are prone to digestive disorders as their owners frequently lack knowledge on proper diet and care.[1] The value of radiography and ultrasonography for investigation of specific abdominal diseases in the green iguana has been reported.[2] Unfortunately, most descriptions of the gastrointestinal anatomy of this species are schematic rather than detailed, containing little clinically helpful information. Generic recommendations for gastrointestinal studies in reptiles have been published, but specific details of techniques for the green iguana are lacking.[3]

The objective of this study was to report the normal contrast radiographic anatomy of the gastrointestinal tract of the green iguana, the approximate transit time through the gastrointestinal tract, and to determine appropriate timing for filming in patients. Results from dissection and fluoroscopic evaluation of gastrointestinal motility are included.

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Materials and Methods

Five adult green iguanas (*Iguana iguana*), three males and two females, weighing 0.8 to 3.9 kg, were studied. These iguanas had been purchased as adults from a commercial source. Their prior history was unknown. Blood was collected for hematologic and biochemical analysis 4 weeks before the commencement of this study. The iguanas were normal on physical examinations performed in the intervening period. The iguanas were housed in a separate group in a large room and were allowed free range over basking platforms, tree branches, and climbing apparatuses. Two full spectrum ultraviolet lights and three heat lamps were positioned over separate basking platforms. The room was maintained at approximately 27–29°C. The iguanas were fed once daily with a variety of leafy greens, which is the standard diet fed to iguanas at this Institution. Food was provided free choice and was generally consumed within 8 to 12 h. Water was constantly available. The group was monitored daily for overall food intake and fecal appearance. The skin colour and behaviour of individuals was also assessed.

The iguanas were transported between the housing facility and the radiology suite in a plastic small animal crate. Iguanas 1 and 5 were restrained using only the vaso-vagal response. These iguanas were positioned for radiography while light digital pressure was applied to the eyelids, either directly or through a towel used as a blindfold. The iguanas became still for a period of at least 15 seconds, allowing the exposure to be made without manual restraint. The other three iguanas were less cooperative and required additional restraint. These animals were placed in sternal recumbency in a radiolucent trough.* The hind legs were extended and the iguana was manually restrained, while a towel was draped over the head and a radiolucent foam pad was placed along the dorsum. The iguana was maintained in this position using either tape,† or cotton rope wrapped around the foam and trough. This provided effective restraint for up to 15 min.

The iguanas were manually restrained for barium administration by wrapping them in a towel. The mouth was gently opened by manual traction, and a 15 cm long rigid metal stomach tube was gently inserted through the mouth into the esophagus. Twenty five millilitres per kilogram of a 105% w/v barium sulphate suspension,‡ diluted with tap water to the concentrations shown in Table 1, was administered through the stomach tube.

Vertical beam dorsoventral and horizontal beam standing right lateral radiographs were made prior to administration of barium. The same projections were made immediately following the barium administration and at 30 min, 1, 2, 3, 4, 5, 6, 8, 12, 16, 20, 24, 36, 48, 60, and 72 h after barium administration. Gastric and intestinal motility was observed fluoroscopically in each iguana for approximately 1 min at time 0, 30 min, 1 h, and 4 h after barium administration. Iguana 1 was also evaluated at 24 h and 48 h to observe colonic motility. The iguanas were evaluated fluoroscopically in sternal recumbency with a vertical beam at all evaluations and with a horizontal beam at time 0, 30 min, and 1 h. All examinations were recorded on videotape. No attempt was made to quantify the rate of peristaltic contractions.

For the first 24 h of the protocol it was impractical to transport the iguanas between the housing facility and the radiography suite for each series of radiographs. Consequently, for this period, the iguanas were held in an incubator at 29.4°C in the Veterinary Teaching Hospital. After 24 h, each iguana was returned to the group housing environment where it remained between radiographs. A second contrast study was performed in iguana 1 with the iguana housed in an incubator with the temperature reduced to 24°C. Based on the findings in the main study, the number of radiographs was reduced. Radiographs were made at time 0, and at 1, 4, 8, 12, 24, 36, 48, 60, 72, and 96 h after barium administration. Data were also used from a contrast study involving a female pet iguana that had previously been used as a control for a clinical patient. No clinical evidence of disease was identified in this iguana before or after the contrast study. This iguana (number 6) had been maintained

*Surgi-Form Troughs, Carlin Enterprises; Tulsa Oklahoma, USA.
†Vet Wrap, 3M Canada Inc; London, Ontario, Canada.
‡Liquid Polibar Plus, Therapex, division of E-Z-EM Canada Inc; Montreal, Quebec, Canada.

TABLE 1. Individual Gender, Weight, Volume and Concentration of Barium Sulphate Solution Given to Each Iguana

Iguana	Gender	Weight (kg)	Volume (ml)	% Ba
1	F	0.8	20.0	105
2	F	1.7	42.5	25
3	M	1.3	32.5	50
4	M	2.8	70.0	25
5	M	3.9	100.0	25

at 24°C and had been given 10 ml/kg of a 105%w/v suspension of barium. The weight of the iguana had not been recorded. Radiographs were made at 0, and 15 min, and at 1, 3, 6, 10, 24, 32, 50, 99, 123, and 147 h after barium administration.

Two iguanas that had been euthanised for reasons unrelated to the gastrointestinal tract and were not a part of this study were examined grossly to correlate anatomic and radiographic findings. The gastrointestinal system was viewed *in situ,* then removed in its entirety and examined in greater detail. Internal and external features were identified and recorded.

Results

Throughout the study the iguanas were active and appeared healthy. Complete blood counts and biochemical profiles were within normal reference ranges for iguanas.[4] Food intake was reduced during the 24-hour period in the incubator, except for iguana 4, which maintained a normal appetite. Food intake returned to normal on return to the usual housing. The appearance of the abdomen on the scout radiographs was dominated by the colonic content. It was not possible to separately identify the stomach or the small intestine. The restraint and barium administration techniques were well tolerated. Iguanas 2, 3, and 4 regurgitated small amounts of barium during or immediately following its administration. Of the three concentrations used, the 25% w/v suspension provided the best images. With the more concentrated suspensions the anatomic features were not easily distinguished, especially where loops of intestine overlapped. Twenty five millilitres per kilogram was adequate for visualization of the entire gastrointestinal tract.

In the green iguana, the thoracic esophagus travels dorsally along the midline. It joins the stomach at the level of the liver, to the left of midline. Grossly, the esophageal mucosa had a few smooth, unbranched, longitudinal folds. Barium was only seen briefly in the esophagus of individuals that had regurgitated the barium suspension during administration. The longitudinal folds of the esophagus near the junction with the stomach were visible as radiopaque lines (Figs. 1 and 2a,b). The stomach had a distinct U-shape on radiographs, which was consistent with the post-mortem anatomic observations. The segments of the stomach were labelled descending, transverse, and ascending (Figs. 1 and 2a,b). The descending portion lies dorsally adjacent to the

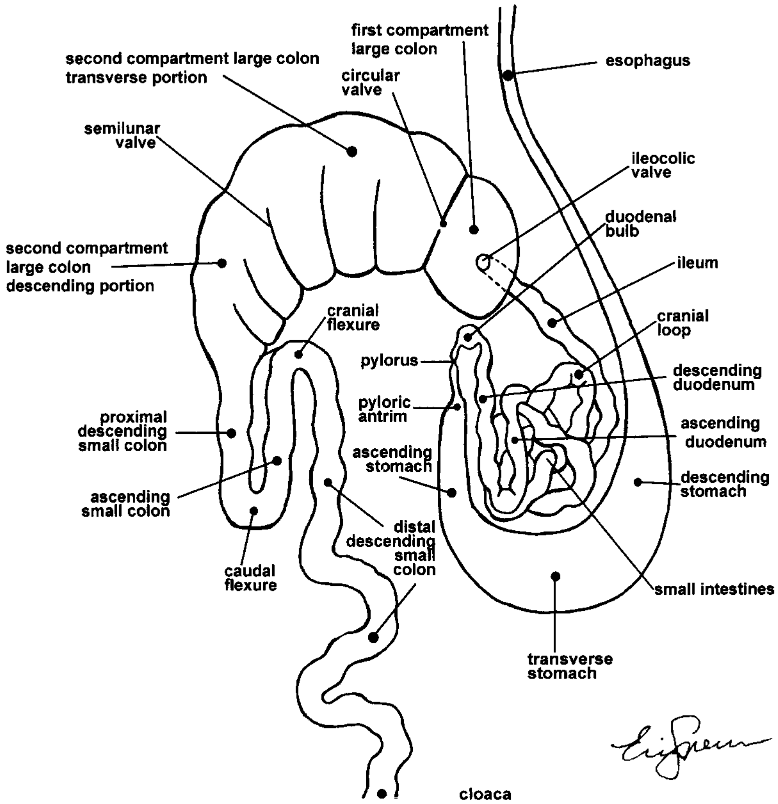

FIG. 1. Outline diagram of the relationships of the gastrointestinal tract of the green iguana.

left flank and to the left of the small intestine, while the ascending portion lies ventrally, and to the right, of the small intestine. Filling defects that may correspond to residual food material were noted in the stomach (Fig. 2a,b). When distended with barium, the internal outline of the stomach was smooth with no visible rugae. However, when the internal surface was examined during dissection, rugal folds were easily observed.

Radiographically, the pyloric antrum was visible as a distinct narrowing of the ascending stomach, just proximal to the pylorus. The duodenal bulb emerging from the pylorus appeared as a round enlargement, with its lumen narrowing at the entry to the proximal duodenum. Barium was visible as a thin column within the pyloric sphincter, collecting in the bulb before passing into the duodenum. A 180° flexure was present at the junction of the pylorus and the duodenal bulb, immediately caudal to the liver, and to the right of the midline (Figs. 1 and 2c). Two distinct regions of the duodenum were distinguished, and were designated as descending and ascending parts. The descending part passed caudally, then curved 180° to become the ascending part (Fig. 1). Beyond the duodenum, the jejunum became highly coiled (Figs. 1 and 2d). A single loop of jejunum seen cranial and to the left of the intestinal coils was repeatedly identifiable on radiographs, and was labelled the cranial loop (Figs. 1 and 2d). The cranial loop could not be specifically identified on gross dissection.

On the radiographs the ileum was located cranial and to the left of the intestinal coils, and dorsal to the descending stomach (Figs. 1, and 2e,f). As the more distal portions of the tract filled with barium it became difficult to differentiate ileum, colon, and the cranial loop as they were typically superimposed upon each other. The ileum extended along the dorsal surface of the proximal colon and entered the first compartment of the large colon at approximately the mid-point (Figs. 1, 2f, and 3a). The exact point of entry could not be distinguished radiographically.

The colon was the largest and most complex portion of gut observed. The large colon lies dorsal to the remainder of the gastrointestinal tract. It has a distinct C-shape, with the outer curvature lying cranially against the liver, and laterally against the right abdominal wall (Figs. 1 and 3b,c,d). The large colon is divided into two parts. The first compartment is delineated by a circular valve, which could be identified radiographically (Fig. 3b,c). The second compartment comprises the remainder of the large colon and has transverse and descending parts. The barium initially filled the first compartment before passing through the circular valve into the second compartment. The second compartment is prominently compartmentalized by semi-lunar valves. The junction between the large and small colon is marked by a reduction in caliber. Two 180° flexures separated the proximal descending, ascending, and distal descending parts of the small colon. The ascending and proximal descending

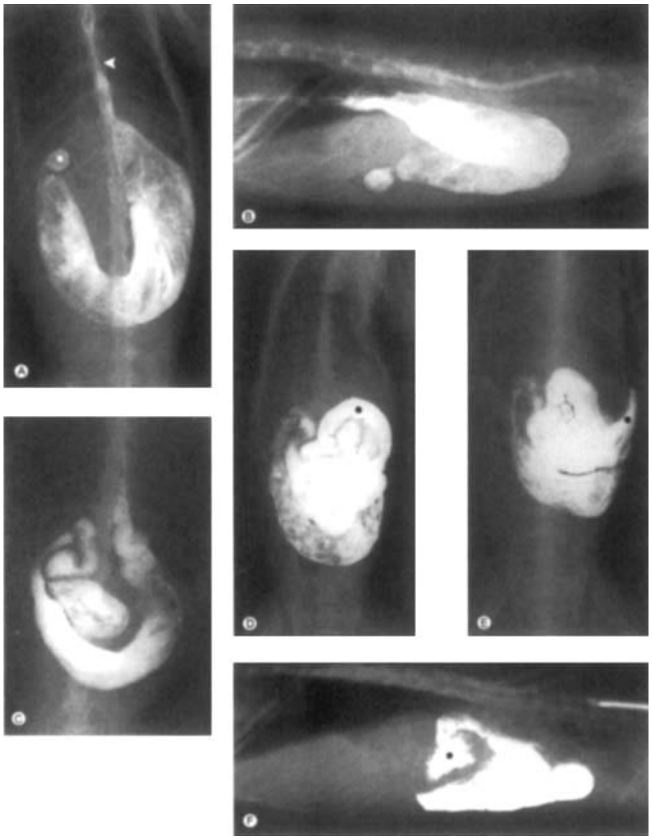

FIG. 2. A) Dorsoventral (DV) radiograph of iguana 2 immediately after barium administration. Note residual barium in esophageal folds (arrowhead), U-shaped stomach, pyloric antrum, and duodenal bulb (asterisk). B) Lateral radiograph of iguana 2 immediately after barium administration. Note dorsal position of descending stomach to ventral position of ascending stomach. The duodenal bulb is identified cranio-ventrally. C) DV radiograph of iguana 4 made 30 minutes after barium administration. Note barium in pyloric antrum, descending and ascending duodenum. Descending stomach is emptying of barium. An impression in the ascending stomach wall due to peristalsis can be identified. D) DV radiograph of iguana 1 made 2 h after barium administration. The stomach is largely empty while the small intestine is filled with barium. Note the cranial loop (asterisk) present in the left cranial quadrant. E) DV radiograph of iguana 3, made 4 h after barium administration. Note barium within ileum located along the left flank (asterisk). F) Lateral radiograph of iguana 3 made 6 h after barium administration. Note ventral position of stomach and small intestines, all of which are overlapped. The ileum can be identified lying dorsal to small intestine and entering the first compartment of the large colon on the dorsal aspect (asterisk).

colon are in direct contact and lie within the same mesentery (Figs. 1 and 3e,f). Distal to the common mesentery, the distal descending colon followed a somewhat tortuous path to the cloaca.

The location of the barium at the different time intervals is presented in Table 2. Gastric emptying commenced rapidly, with barium being present in the duodenal bulb on the immediate radiographs in 4 of the 5 iguanas. In the cold iguana (second study, iguana number 1), and in the iguana receiving the low barium dose (Number 6), commencement of gastric emptying was prolonged to 3 h and 1 h, respectively. Gastric emptying was complete at a median time of 8 h (range 6–12 h), and was delayed to 24 h in the cold and cold, low barium dose iguanas. Median small intestinal transit and small intestine emptying times were 4 h (range 4–6 h) and 16 h (range 12–16 h) respectively. In the cold iguana these values were prolonged to 7 h and 23 h and to 7 h and 29 h in the cold, low barium dose iguana. Median large colon transit and emptying times were 15 h (range 3–27 h) and 66 h (range 33–68 h), while they were 18 h and 112 h in the cold iguana and 40 h and 147 h in the cold, low barium dose iguana.

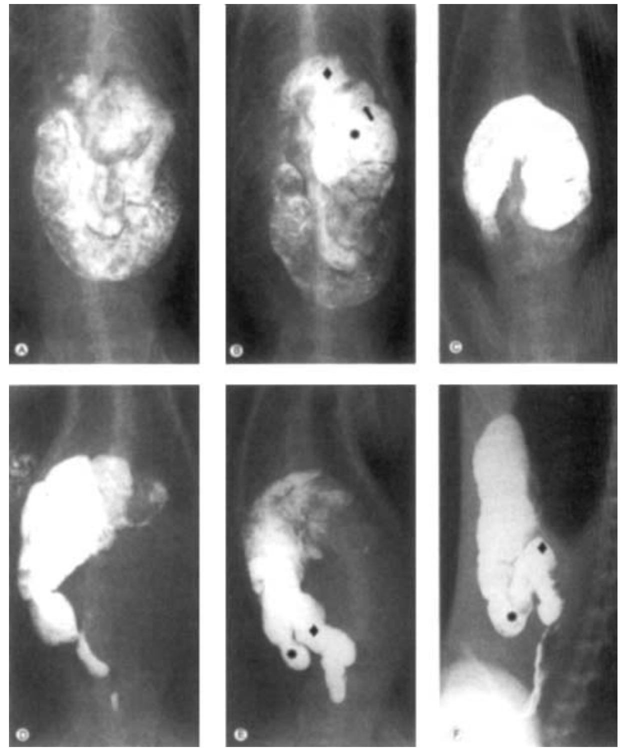

FIG. 3. A) DV radiograph of iguana 2 made 5 h after barium administration. Residual barium can be identified in the stomach and the descending duodenum. Barium can be identified in the ileum as it enters the first compartment of the large colon. B) DV radiograph of iguana 6 made 8 h after barium administration. The first compartment of the colon (asterisk) and the transverse colon (diamond) can be identified as the barium progresses through the circular valve (arrow). C) DV radiograph of iguana 1 made 16 h after barium administration. All of the large colon and the circular and semi-circular valves can be identified. D) DV radiograph of iguana 1 made 36 h after barium administration. The first compartment of the large colon is beginning to empty. Barium can be identified in parts of the small colon. E) DV radiograph of iguana 1 made 48 h after barium administration. The caudal (asterisk) flexure and the distal descending (diamond) limb of the small colon can be identified overlying the large colon. F) Lateral radiograph of iguana 5 made 24 h after barium administration. The large colon and the proximal descending, ascending, distal descending limbs, and cranial (diamond) and caudal (asterisk) flexures of the small colon can be identified.

Fluoroscopically there was almost imperceptible gastric motility, despite rapid commencement of gastric emptying. Small intestinal peristaltic activity was slightly slower than

TABLE 2. Time (h) at Which Barium First Entered (Top Row) and Had Completely Left (Bottom Row) Each Segment of the Gastrointestinal Tract

	Iguana							
	1	2	3	4	5	Median	6	1 (cold)
Esophagus	0	0	0	0	0	0	0.25	
	0.5	0.5	0.5	1	0.5	0.5	1	
Descending stomach	0	0	0	0	0	0	0.25	0
	3	12	2	2	4	3	1	1
Transverse stomach	0	0	0	0	0	0	1	0
	8	12	8	6	8	8	10	24
Ascending stomach	0.5	0	0	0	0	0	1	0
	12	12	8	6	8	8	24	24
Pyloric antrum	0.5	0	0	0	0	0	3	1
	12	12	8	6	8	8	24	24
Pylorus	0.5	0	0	0	0	0	3	1
	12	12	8	6	8	8	24	24
Duodenal bulb	0.3	0	0	0	0	0	3	1
	12	12	8	6	8	8	24	24
Descending duodenum	0.5	0.5	0	0	0.5	0.5	3	1
	16	16	12	8	8	12	24	24
Ascending duodenum	0.5	2	1	0.5	1	1	3	1
	16	16	16	12	12	16	24	24
Small intestines	1	3	2	1	2	2	6	1
	20	16	16	12	16	16	24	36
Cranial loop	*	3	3	2	3	3	10	4
	*	16	16	12	16	16	*	24
Ileum	*	5	6	4	5	5	24	*
	*	16	16	12	16	16	32	*
First compartment of large colon	4	5	6	3	3	4	10	8
	60	60	60	72	30	60	50	120
Second compartment of large colon	5	6	8	6	3	6	24	8
	72	72	72	72	36	72	147	120
Proximal descending Colon†	16	20	24	30	6	20	50	24
Caudal flexure†	16	20	30	36	8	20	99	24
Ascending colon†	20	24	36	36	12	24	99	24
Cranial flexure†	24	30	48	48	16	30	99	36
Distal descending colon†	72	72	72	60	36	72	147	120

*Barium column was not sufficiently distinct to accurately determine the time of entry or exit in this segment.
†Only the time that barium entered the small colon was recorded.

that observed in mammalian species. However, occasional peristaltic rushes were identified where a single peristaltic wave would rapidly propel the leading edge of the barium column up to 10 cm along the lumen of the intestine. No evidence of colonic peristaltic activity was identified. Fluoroscopy in the ventrodorsal projection was more rewarding than in the standing lateral projection, as there was considerably less superimposition of the various segments of the digestive tract.

Discussion

There is considerable diversity in the gastrointestinal anatomy of the reptiles. Consequently, comparison with other similar species may be misleading. The large intestine of the green iguana has unique modifications, the segmentation of the large colon and the semilunar valves, that are not present in other lizards.[5] This study is a detailed description of the gross morphology and radiographic anatomy of the gastrointestinal tract of the green iguana. Several of the segments of the digestive tract identified in this study have not previously been described specifically. For example, the anatomy of the colon of the green iguana is complex with no clear agreement on nomenclature. The first compartment of the large colon has been variously described as an antechamber, the colic cecum, and the cecum.[5–7] Regardless, this compartment would appear to be analogous to the mammalian cecum, with the circular valve being the equivalent of the cecocolic valve.

Significant individual variation in intestinal transit and emptying occur, particularly in the small intestine as demonstrated by iguana number 5. Additionally, both a lower ambient temperature and a lower dose of barium appear to result in marked reduction in the rate of passage of the contrast medium through the gastrointestinal tract. Iguanas are ectotherms, with their body temperature and metabolic rate fluctuating with the environmental temperature. The rate of passage of food through the gastrointestinal tract is influenced by a variety of intrinsic and extrinsic factors, including ambient temperature and the temperature dependant rate of secretion and activity of digestive enzymes.[8] Intuitively, it is probable that gastrointestinal transit time will be prolonged at lower temperatures. Caution should be exercized in extrapolating the results of this study to other species, as the transit time through the entire digestive tract has been reported as being 3 to 6 days in carnivorous lizards, compared to 15–30 days in herbivorous lizards.[9] A number of variables were present in the study that may have influenced the results. It is possible that the use of the vaso-vagal response for restraint in some of the iguanas may have also influenced gastro-intestinal motility due to its effects on the autonomic nervous system. Further studies would be required to investigate this potential effect. Although the subjects were all adult, the wide range in size may have been an influence on the transit time. The use of different concentrations of barium may also have influenced the outcome, although we are not aware of this effect having been previously reported. Similarly, conclusions based on the effect of hypothermia and comparison with Iguana 6, which had a smaller dose of contrast medium, must be tentative because only a single individual was involved.

Short filming intervals were chosen on an empirical basis for this study so that appropriate timing of films for clinical use could be identified. Our recommendations for contrast studies of the gastrointestinal tract of the green iguana maintained at a constant environmental temperature of 27–29°C are as follows. A 25 ml/kg dose of contrast medium is adequate for appropriate distension of the stomach and subsequent visualization of the remainder of the gastrointestinal tract. Fifty millilitres per kilogram has been recommended as a generic dose of barium for lizards.[9] We believe this is excessive for the green iguana. An even smaller dose may be appropriate since 3 of the 5 iguanas regurgitated with the 25 ml/kg dose. A 25%w/v suspension is the most appropriate barium dilution examined in this study. Lateral and ventrodorsal projections of the abdomen should be made immediately following administration of barium and at 1-hour intervals for the first 6 h. At this time, the contrast medium should be in the first compartment of the large colon in most individuals. We recommend that radiographs be made at 12-hour intervals thereafter until barium can be identified in the distal descending small colon. Clearly, the presence of pathology may require that the timing be modified on an individual basis.

Finally, we found that the vaso-vagal response was an effective restraint method for cooperative iguanas. The mechanical restraint described for the less cooperative individuals was equally effective when required. The restraint was effective for up to 15 min, the maximum time that it was required for. Repeat handling did not modify the behavior of individual iguanas, either positively or negatively.

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