THE NORMAL UPPER GASTROINTESTINAL EXAMINATION IN THE FERRET

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Upper gastrointestinal examinations were performed in 11 unsedated ferrets and 4 ferrets sedated with ketamine and diazepam. Each animal received a 8–13 mL/kg body weight dosage of barium liquid (30% weight:volume). Radiographs were made immediately and at 5, 10, 20, 40, 60, 90, 120 and 150 min (mins) after the barium was administered. Gastric emptying began immediately. Mean total gastric emptying was longer in sedated ferrets (130 ± 40 min versus 75 ± 54 min); however, this difference was not statistically significant ($p = 0.18$). Small intestinal transit time was less than 2 h in all ferrets. The barium-filled small bowel was best visualized on the 20- and 40-min radiographs and did not exceed 5–7 mm in width. Flocculation of barium in the small intestine and adherence of barium to the stomach mucosa was seen in almost all animals. The longitudinal colonic mucosal folds in the colon were well visualized in the normal upper gastrointestinal study and aided in distinguishing small intestine from large intestine. The use of ketamine and diazepam sedation did not significantly affect the parameters evaluated in the upper gastrointestinal study series. *Veterinary Radiology & Ultrasound, Vol. 44, No. 2, 2003, pp 165–172.*

Key words: ferret, gastrointestinal studies, UGI study, barium, ketamine, diazepam.

Introduction

THE INCREASING POPULARITY of ferrets as pets and research models necessitates a greater knowledge of ferret physiology and disease. However, aside from imaging the adrenal gland, there is still little information on ferret diagnostic imaging procedures. Ferrets are hosts for many gastrointestinal diseases, including bacterial and viral enteritis, eosinophilic gastroenteritis, *Helicobacter mustelae (H. mustelae)*—induced gastrointestinal ulceration, foreign body obstruction and neoplasms, such as lymphoma or adenocarcinoma.[1–4] Diagnostic imaging procedures therefore may play an important role in the diagnosis and management of disease processes in the ferret. Survey radiography and ultrasonography are often used in the ferret. However, a gastrointestinal contrast study, such as an upper gastrointestinal (UGI) series is infrequently performed and has been used primarily to confirm a tentative diagnosis of a small intestine foreign body obstruction.[3] UGIs have played an important role in diagnostic imaging of the gastrointestinal tract in other species[5–8] and may serve an important role in diagnosing gastrointestinal diseases in the ferret. However, the normal radiographic features of the ferret gastrointestinal tract must be established before the assessment of abnormalities.

The anatomy of the ferret (Fig. 1) and its close relative the mink have been well documented and are very similar.[9–11] On gross examination, the ferret has a simple, noncompartmentalized stomach[12] which, from a ventral view, lies perpendicular to the axis of the spine with the body of the stomach positioned near midline.[13] Small intestinal length ranges from 182 to 198 cm.[13] Although the diameter of the ferret small intestine has not been reported, the diameter of the empty small intestine in the mink was similar to the colon and measured 0.6 cm.[10] The ferret lacks a cecum and the jejunal–ileal and ileocolic junctions are distinguishable only upon histologic examination.[13] The colonic and rectal portion of the large intestine is approximately 10 cm in length by 0.6 cm in diameter.[13]

Radiographically, on a left lateral projection, the stomach inclines on a transverse plane at approximately 45 degrees.[13] On a ventrodorsal (VD) radiograph, the stomach is J-shaped, similar to the cat. The cranial border of the stomach is at the level of the thirteenth thoracic vertebra.[13]

Normal ferrets have a small amount of gas within the gastrointestinal tract.[14] Gaseous distention of the stomach and small intestine have been described as indicators of a foreign body obstruction.[2] Although postmortem measurements of the ferret small intestine and colon have been reported, the normal range for the width of the small intes-

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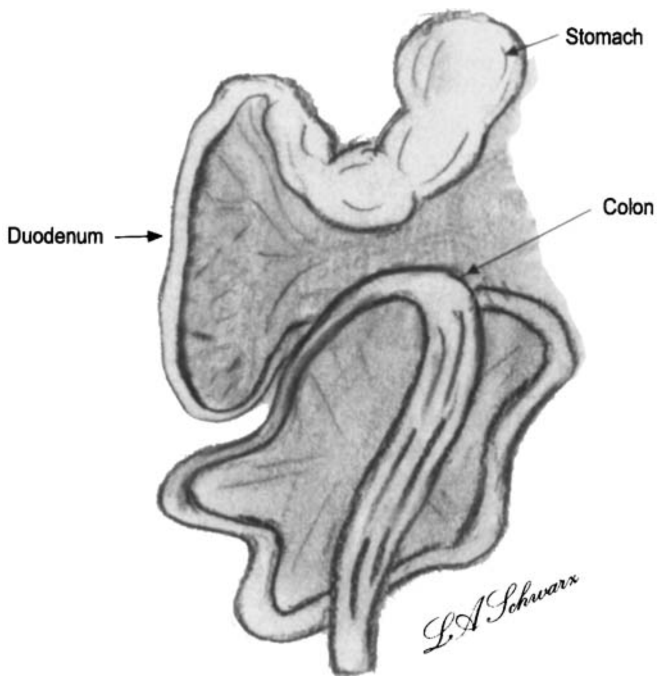

FIG. 1. Illustration of the gastrointestinal tract of the ferret viewed from a ventral perspective. Length of the small intestine is not drawn to scale. Compare the position of the duodenum to Fig. 3B and the mucosal folds of the colon to Fig. 5B. Adapted from Poddar S and Murgatroyd L. Morphological and histological study of the gastrointestinal tract of the ferret. Acta Anat 1976;96:324.

tine and colon, identified radiographically, has not been determined.

The normal gastrointestinal transit time in the ferret was established by using a dye marker added to feed, is 181.8 ± 6.7 (mean ± standard error of the mean) min.[15] However, because solids and liquids pass through the digestive tract at different rates,[16] the transit time of barium liquid suspension should differ from the dye food mixture. The normal transit time of barium liquid suspension through the ferret gastrointestinal tract has not yet been established.

The goals of this study were to 1) describe the radiographic anatomy of the ferret gastrointestinal tract; 2) determine the normal transit time of barium liquid suspension through the ferret gastrointestinal tract; and 3) evaluate the effect of ketamine and diazepam sedation on gastrointestinal transit time in a barium liquid UGI series.

Materials and Methods

The study group consisted of 11 ferrets: 5 neutered males, 1 neutered female, 1 intact male and 4 intact females. The mean age of the ferrets was 2.8 years (range 1.4–5.5 years) and mean weight was 1.0 kg (2.2 lbs) with a range of 0.8–1.8 kgs (1.8–4.0 lbs). Six ferrets were client-owned animals, and five healthy ferrets were part of a research colony. No attempt was made to standardize the diet or housing of these animals. Research ferrets were housed in an Association for the Assessment and Accreditation of Laboratory Animals—accredited animal resource facility. All animals were clinically normal at the time of the study and did not have a history of gastrointestinal disease. The ferrets were fasted approximately 8 h before the UGI study. Survey radiographs were obtained immediately before the administration of the contrast medium to verify that the gastrointestinal tract was empty.

A barium UGI series was performed in all ferrets without the use of sedation. A 8–13 mL/kg bodyweight (BW) dose of barium liquid suspension (30% weight:volume)* was administered to each ferret. The unsedated ferrets were restrained in a scruffed elevated position and the barium was given orally via a curved-tip dosing syringe. UGI study examinations were repeated in five of the 11 ferrets with the use of sedation. In the ferrets sedated with an intramuscular (IM) combination of ketamine† (20–30 mg/kg BW) and diazepam‡ (1 mg/kg BW IM)[17] an orogastric tube was used to deliver a 8–13 mL/kg BW dose of barium liquid into the stomach. Atropine was not used as part of the sedation protocol so as not to alter intestinal motility. Correct placement of the tube into the stomach was confirmed with fluoroscopy before administrating contrast medium. One sedated ferret vomited a substantial portion of the barium dose immediately after administration. The data from this ferret were not included in the study.

The radiographic series for the UGI study was the same for both the unsedated and sedated ferrets. Survey right lateral and VD radiographs were obtained for each animal. After barium was given, immediate right and left lateral, VD, and dorsoventral (DV) radiographs were obtained. Right lateral and VD radiographs were obtained in all animals 5, 10, 20, 40, 60, 90, and 120 min after barium administration. Radiographs were taken 150 min after barium administration in one case in which barium was still present in the stomach at 120 min.

Observations were recorded from the survey radiographs and the UGI study series. From the UGI study series, the following radiographic parameters were evaluated: onset of gastric emptying, mean total gastric emptying time, small intestinal transit time, and maximal small intestinal distention. The onset of gastric emptying was defined as the first radiographic time period at which barium was seen in the small intestines. Total gastric emptying time was defined as the radiographic time period at which barium had left the stomach. When the amount of barium left in the stomach consisted of only barium adhering to the rugal folds of the stomach, gastric emptying was considered to be complete. Finally, small intestinal transit time was defined as the first radiographic time period at which barium was seen in the

*Polibar Liquid, E-Z-EM Inc., Westbury, NY.
†Ketaset®, Fort-Dodge, Fort Dodge, IA
‡Valium®, Roche, Nutley, NJ

colon. Because the majority of the small intestines were barium filled on the 40-min radiographs, this time was chosen to measure the mean maximal small intestinal distention. The width of the largest three small intestinal segments was measured by the film reader on the 40-min film for each ferret. Additional observations included the presence or absence of barium adherence to the stomach wall after gastric emptying was considered to be complete, the presence or absence of flocculation of barium in the small intestine, and visualization of parallel longitudinal filling defects in the colon. Radiographic interpretation was performed by two radiologists (LS and MS), who were not aware of the patient identification or status (sedated or unsedated) at the time of the reading of the radiographs. Analysis of the data consisted of a paired *t* test which was performed on the results of the variables evaluated. A Pearson's correlation test (>0.80) confirmed good statistical correlation between the two radiograph interpreters. Therefore, the results of the radiographic measurements obtained from the two readers were averaged.

A

B

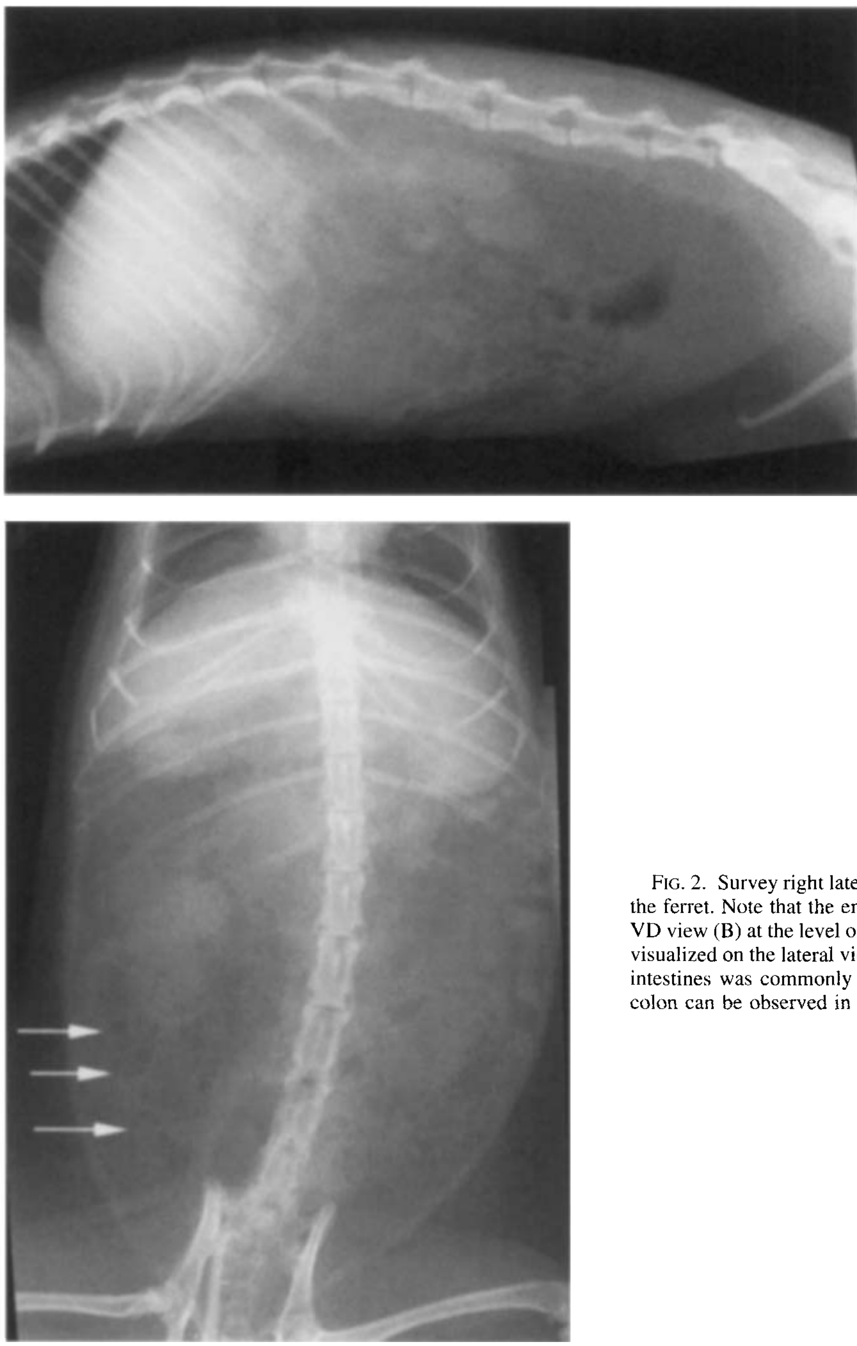

FIG. 2. Survey right lateral (A) and ventrodorsal (B) abdominal radiographs of the ferret. Note that the empty stomach is visible in the cranial abdomen on the VD view (B) at the level of the last two intercostal spaces. The stomach is poorly visualized on the lateral view. The fragmented appearance of the gas in the small intestines was commonly seen in the normal ferret (B, arrows). The gas filled colon can be observed in the caudal abdomen on the lateral view (A).

Results

The unsedated group of ferrets tolerated the oral administration of barium and positioning for radiography well. The sedated ferret UGI studies were technically more difficult to perform. The ketamine–diazepam combination used produced salivation and spasticity in all sedated ferrets, which made handling and radiographing the ferrets difficult. This drug combination also provided only a short time period for effective passage of the stomach tube.

On the survey radiographs, it was often difficult to visualize the empty ferret stomach on the lateral view. On the VD view, the fundus could be seen near midline (Fig. 2B). The empty small intestines usually contained a small amount of gas, often in a fragmented pattern (Fig. 2B). A fragmented gas pattern was defined as well-defined oval or tear-drop shaped interrupted segments of intraluminal small intestinal gas.

After barium administration, the barium-filled stomach was optimally visualized on the immediate radiographs (Fig. 3A and B). It appeared on a VD or DV projection as a J-shaped, simple stomach, which lay perpendicular to the axis of the spine with the fundus to the left of the midline (Fig. 3B). The size and shape of the ferret stomach, seen in

A

B

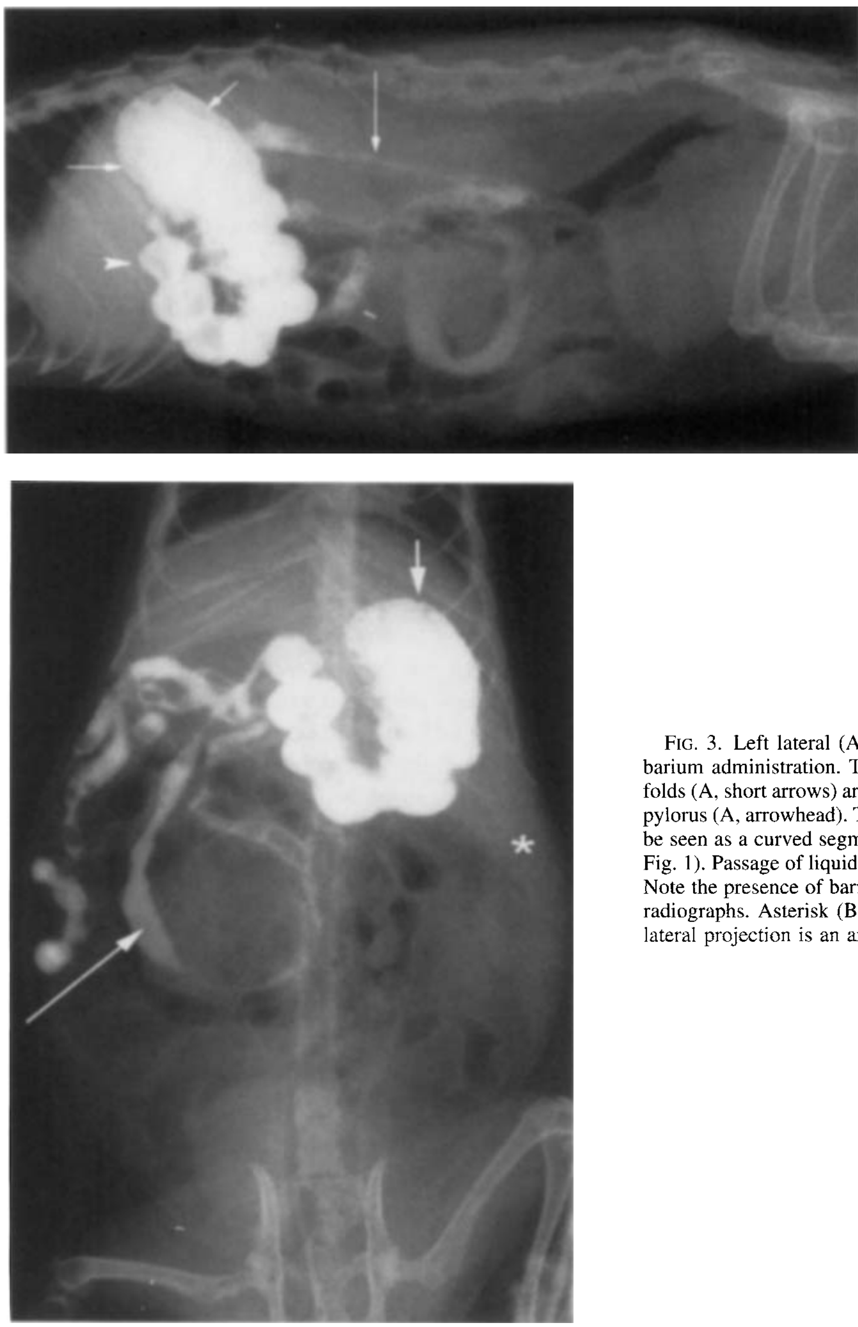

FIG. 3. Left lateral (A) and DV (B) radiographs obtained immediately after barium administration. The stomach is filled with barium but the fundic rugal folds (A, short arrows) are still visible. Note the cranial and dorsal position of the pylorus (A, arrowhead). The barium-filled duodenum (A and B, long arrows) can be seen as a curved segment of bowel in the right cranial abdomen (compare to Fig. 1). Passage of liquid barium through the ferret gastrointestinal tract is rapid. Note the presence of barium in the proximal small intestine on these immediate radiographs. Asterisk (B) indicates the spleen. The small linear opacity on the lateral projection is an artifact caused by debris in the cassette.

this UGI series, was similar to that described for the cat and mink.[6,9–11] Adequate barium filling of the stomach was achieved in both groups of ferrets. However, maximal gastric distention resulting in a rounded appearance of the stomach with loss of visualization of the gastric rugal folds was not observed.

The pylorus was usually located on midline or just to the right of midline on the VD or DV views, with the opening positioned craniodorsally (Fig. 3A and B). The barium-filled duodenum was best seen on the immediate VD or DV radiograph as a curved segment of bowel running along the right lateral body wall (Fig. 3B) with the descending portion of the duodenum most consistently visualized. The barium-filled small intestines were optimally evaluated on 20- and 40-min radiographs (Fig. 4A and B). Maximal small intestinal distention, measured on the 40-min radiographs, was 5.9 ± 1.0 mm (mean ± SD) and 5.4 ± 1.3 mm (mean ± SD) for the unsedated and sedated groups of ferrets, respectively. The ferret colon was often difficult to visualize unless it was gas filled (Fig. 2A and B). Although colonic measurements were not taken, subjectively a barium filled colon was wider than the small intestine and appeared as a question mark-shaped structure mainly in the left side of the abdomen (Fig. 5A and B). Parallel longitudinal filling defects in the colon, resulting from the folds in the colonic mucosa, were seen in all ferrets in both the unsedated and

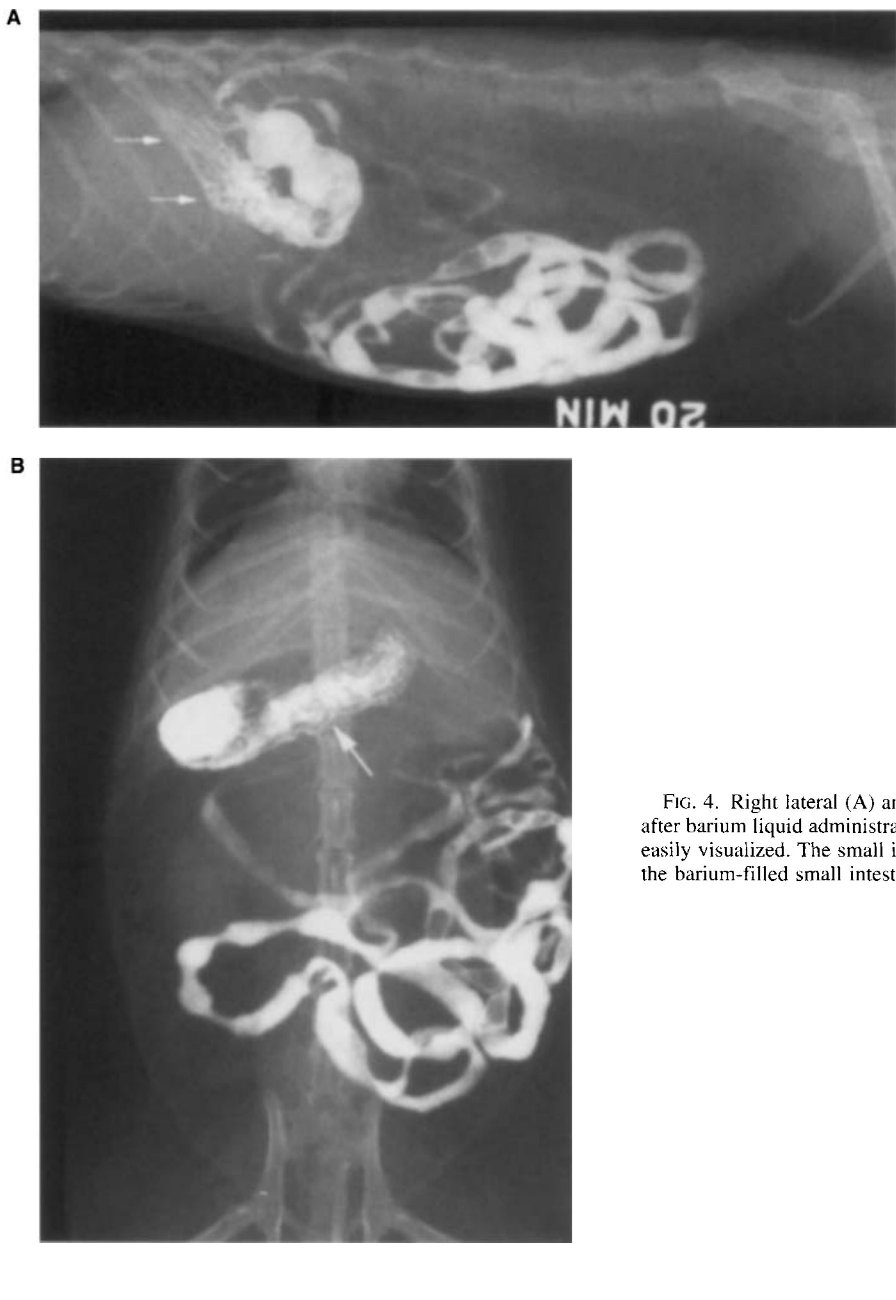

FIG. 4. Right lateral (A) and ventrodorsal (B) radiographs obtained 20 min after barium liquid administration. The rugal folds of the stomach (arrows) are easily visualized. The small intestine is filled with barium. Maximal width of the barium-filled small intestine was 5–7 mm.

sedated ferrets (Fig. 5A and B). These folds were most commonly seen in the transverse and descending portions of the colon.

Transit time of barium was rapid. The onset of gastric emptying was noted on the immediate radiographs in all but one unsedated ferret in which it was observed on the 5-min radiographs. Small intestinal transit time was 74 ± 28.5 min (mean ± SD) in unsedated ferrets and 50 ± 10.7 mins (mean ± SD) in sedated ferrets. The total gastric emptying time in the UGI series of sedated ferrets was longer than in unsedated ferrets (130 ± 40 min (mean ± SD) versus 75 ± 54 min (mean ± SD). However, this difference was not statistically significant ($p = 0.18$). A residual amount of barium adhering to the gastric mucosa (Fig. 5B) was observed radiographically in 10 of 11 unsedated and three of four sedated ferrets. Flocculation or segmentation[5] of barium in the small intestine was seen in all ferrets in both groups (Fig. 6). There was no significant difference between the sedated and unsedated ferrets in the onset of gastric emptying, small intestinal transit time or maximal small intestinal distention.

Discussion

Our data support a barium UGI series as being a rapid, noninvasive, practical method for evaluating the ferret gastrointestinal tract. We also defined some normal parameters for the barium upper gastrointestinal examination in the ferret.

On survey radiographs the empty stomach was often difficult to visualize on the lateral view because all animals

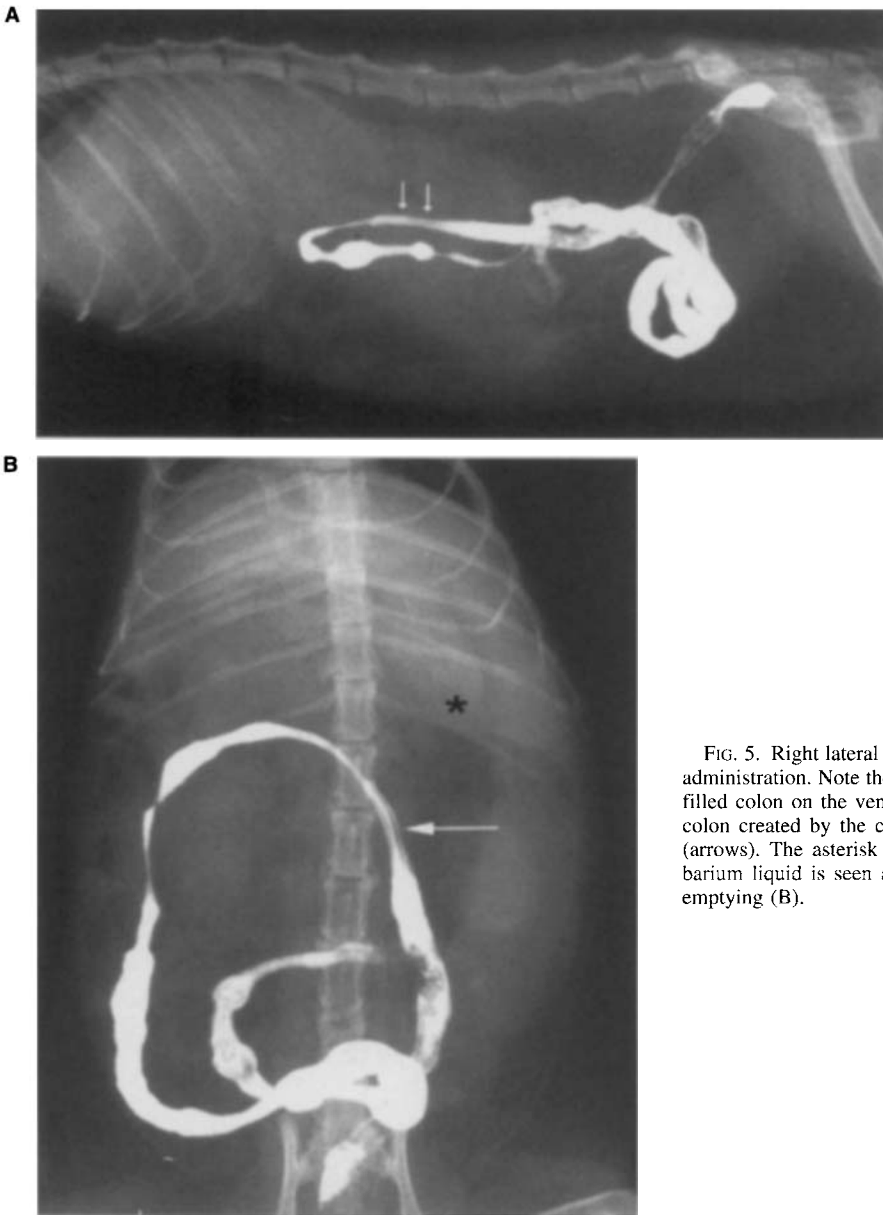

FIG. 5. Right lateral (A) and VD (B) radiographs obtained 1 h after barium administration. Note the curved question mark-like appearance of the barium-filled colon on the ventrodorsal view. The longitudinal filling defects in the colon created by the colonic mucosal folds are evident on both projections (arrows). The asterisk in (B) identifies the stomach. A minimal amount of barium liquid is seen adhering to the gastric mucosa after complete gastric emptying (B).

were fasted before the studies, causing collapse of the lumen of the organ. Presence of gas in the gastric lumen facilitated its identification in some animals. The barium-filled stomach is optimally visualized on immediate radiographs (Fig. 3A and B). It appears on a VD or DV projection as a J-shaped, simple stomach, which lies perpendicular to the axis of the spine near midline. The size and shape and position of the ferret stomach is similar to that previously described for the UGI study in the cat and the gross anatomy of the ferret and mink.[6,9–11,13] However, unlike the previous anatomic description of the mink intestinal tract where small intestines and colon were similar in width,[10] our radiographic observations were that the ferret colon is wider than that of the small intestines.

Passage of barium through the gastrointestinal tract of the ferret is rapid. Gastric emptying begins immediately and is complete by 1.5 to 2.5 h. The appearance of the stomach on immediate films is similar to dogs: a satisfactorily filled stomach on an immediate VD view is characterized by filling of the fundus and pylorus with barium. The body of the stomach on a VD view is filled with gas as air rises to the least dependent portion of the stomach (Fig. 6). On the other hand, the immediate DV view is characterized by complete filling of the body and pylorus with barium. Most of the fundus on an immediate DV view is also filled with barium and the dorsal rugal folds can be seen as air rises to the least dependent portion of the stomach (Fig. 3). The immediate onset and rapid gastric emptying of the ferret may explain why maximal gastric distention causing loss of visualization of the gastric rugal fold was not observed. Another possible explanation is that an insufficient volume of contrast medium was administered to fully distend the stomach. We believe that adequate filling of the stomach was achieved. In this work, adequate filling is defined as the amount of barium needed to visualize the regions of the stomach as described above while subjectively allowing assessment of the wall thickness. We believe that maximal gastric distention was never achieved, which we speculate cannot be performed in a normal ferret UGI study if barium is given per os. Increasing the dose of barium to achieve maximum gastric distention was considered unnecessary for two main reasons: 1) animals may vomit as a result of gastric distention, as is suspected in one subject, and 2) assessing the wall thickness could be performed subjectively with the volume of barium used. Because more objective measurements of wall thickness are likely to be more accurately performed with an ultrasound, it was not assessed in the present animals.

FIG. 6. Flocculation, or clumping of the barium liquid, evident on this 10-min ventrodorsal radiograph (long arrows) was commonly seen in the barium UGI study of the ferret. The rugal folds of the body of the stomach are apparent (short arrow) as gas rises to the most nondependent portion of the organ.

The size, shape, and location of the barium-filled small intestines of the ferret are easily evaluated with a UGI series. The small bowel is best visualized on the 20- and 40-min radiographs and should not exceed 5–7 mm in width (Fig. 4A and B). Small intestinal transit time is approximately 1 to 2 h. Based on the results of this study, the following radiographic sequence for the ferret UGI study is suggested: Precontrast survey right lateral and VD projections and postcontrast immediate right and left lateral, VD, and DV views. Subsequent right lateral and VD radiographs may be obtained at 10, 20, 40, 60, 90, and 120 min. Radiographs taken at 150 min postbarium administration may be used if gastric emptying is not complete. The 5-min time evaluation offered little additional information.

Flocculation of barium in the small intestine and adherence of barium to the stomach mucosa were identified in most ferrets. These were considered to be normal radiographic features of the UGI study in the ferret. We believe that the flocculation may be the result of gastrointestinal mucous mixing with the barium liquid.[5] The longitudinal colonic mucosal folds in the proximal portion of the ferret colon are well visualized in the UGI study and should not be misinterpreted as an intestinal foreign body or parasitism. Measurement of the diameter of the colon was not performed because of variation caused by peristalsis and different amounts of barium at one time in the colon. However, subjectively the colon was felt to be wider than the small intestine. Although mean total gastric emptying was longer in sedated ferrets, the use of ketamine and diazepam sedation did not significantly alter the parameters evaluated in the UGI study. A significant difference might have been proven with a larger sample size.

A difference in the route of contrast medium administration between the unsedated and sedated ferrets was required for two reasons. First, the passage of an orogastric tube in an unsedated ferret is difficult and may result in the ferret swallowing a severed portion of the stomach tube or biting the handler. Second, a high degree of sedation was achieved with the ketamine–diazepam combination, such that the swallowing reflex was impaired. The authors felt that oral administration of contrast medium to the sedated ferrets was contraindicated because of the risk of barium aspiration.

Ketamine and diazepam were the only drugs evaluated in this study. This drug combination was chosen because it has minimal effect on transit time in UGI studies in cats.[18] However, the sedated ferret UGI studies were technically more difficult to perform. The patient salivation and spasticity and a short time period available for stomach tube passage produced by this drug combination made handling and radiographing the ferrets difficult. Even though a lower drug dose might have reduced the salivation and spasticity of the animals, we believe that a lower dosage would not have permitted the passage of a stomach tube. Perhaps the use of different anesthetic drugs would have improved the handling of the sedated ferrets. Although the transit time of barium liquid was not statistically different with the use of the ketamine–diazepam combination, the authors do not recommend its use when performing an upper gastrointestinal contrast exam in the ferret.

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