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Authors: Bloch, Rebecca A., Cronin, Kimberly, Hoover, John P., Pechman, Robert D., and Payton, Mark E.

Source: Journal of Avian Medicine and Surgery, 24(1) : 1-8

Published By: Association of Avian Veterinarians

URL: https://doi.org/10.1647/2008-043R.1

Journal of Avian Medicine and Surgery 24(1):1–8, 2010

Original Studies

Evaluation of Gastrointestinal Tract Transit Times Using Barium-Impregnated Polyethylene Spheres and Barium Sulfate Suspension in a Domestic Pigeon (*Columba livia*) Model

Rebecca A. Bloch, DVM, Kimberly Cronin, DVM, John P. Hoover, DVM, MS, Dipl AVBP, Dipl ACVIM, Robert D. Pechman, DVM, Dipl ACVR, and Mark E. Payton, PhD

Abstract: Barium impregnated polyethylene spheres (BIPS) are used in small animal medicine as an alternative to barium sulfate for radiographic studies of the gastrointestinal tract. To determine the usefulness of BIPS as an alternative to barium suspension in measuring gastrointestinal (GI) transit time for avian species, ventrodorsal radiographs were used to follow the passage of BIPS and 30% barium sulfate suspension through the GI tracts of domestic pigeons (*Columba livia*). Gastrointestinal transit times of thirty 1.5-mm BIPS administered in moistened gelatin capsules and 30% barium sulfate suspension gavaged into the crop were compared in 6 pigeons. Although the barium suspension passed out of the GI tract of all pigeons within 24 hours, the 1.5-mm BIPS remained in the ventriculus for 368.0 ± 176.8 hours and did not clear the GI tract for 424.0 ± 204.6 hours. Although the times for passage of BIPS and 30% barium sulfate suspension from the crop into the ventriculus were not significantly different ($P = .14$), the times for passage of BIPS from the ventriculus into the large intestine-cloaca and for clearance from the GI tract of the pigeons were significantly longer ($P < .001$) than for the 30% barium sulfate suspension. From the results of this study, we conclude that BIPS are not useful for radiographically evaluating GI transit times in pigeons and are unlikely to be useful in other avian species that have a muscular ventriculus. BIPS may or may not be useful for evaluating GI transit times in species that lack a muscular ventriculus.

Key words: barium-impregnated polyethylene spheres, BIPS, barium sulfate suspension, gastrointestinal transit, avian, pigeon, *Columba livia*

Introduction

Disorders of gastric emptying and intestinal transit affect all species of animals. Causes can range from diseases that cause obstruction, such as mass lesions, pyloric hypertrophy, or gastric foreign bodies, to diseases that cause changes in motility, such as inflammation, metabolic disorders, or electrolyte disorders.[1] Nuclear scintigraphy is the gold standard for diagnosis of altered motility in humans but is cost prohibitive and often impractical in animals.[1] Generally, the gastrointestinal (GI) tract of birds has been investigated in 2 ways. In domestic poultry, GI tract transit times and nutrient absorption are evaluated by using feed that is labeled with chromic oxide or titanium oxide. A known quantity of food is fed at time zero, and the resultant feces are collected and analyzed for marker amounts. A mathematical calculation then is used to determine transit time for various feeds.[2,3] In pet and captive avian species, barium sulfate suspension has been used to assess GI structure, as well as to observe GI transit. Barium transit times have been reported for canaries (*Serinus canaria*), hawks, racing pigeons (*Co-*

From the Center for Veterinary Health Sciences (Bloch, Cronin, Hoover, Pechman) and the Department of Statistics (Payton), Oklahoma State University, Stillwater, OK 74078, USA. Present address: Fossil Rim Wildlife Center, 2155 County Road 2008, Glen Rose, TX 76043, USA (Bloch); 150 Rachel Way, Athens, GA 30605, USA (Cronin).

lumba livia), mynahs, pheasants, and various psittacine bird species.[4,5] Although similarities exist, barium suspension GI transit times vary among species of birds.

An alternative to both labeled feed and barium suspension is the use of barium-impregnated polyethylene spheres (BIPS, Medical I.D. Systems Inc, Grand Rapids, MI, USA). The use of BIPS has been investigated in cats and dogs with 2 differently sized particles.[1,6] The 1.5-mm BIPS are intended to mimic the passage of food in the GI tract, whereas 5-mm BIPS are used to detect GI-tract obstructions. [6] Although BIPS do not give as much information about structural lesions of the digestive tract, they do offer important information on GI motility, by indicating GI transit time and the presence of obstructions without detracting from visibility of abdominal structures. BIPS have been used to characterize the flow of digesta in 4 lemur species,[7] but no reports were found on the use of BIPS in avian species. The purpose of this study was 1) to determine if BIPS would be useful in birds to determine GI transit time and 2) to compare the GI transit times of BIPS with that of liquid barium suspension in a domestic pigeon model.

Materials and Methods

This study was conducted under an approved protocol by the Oklahoma State University Animal Care and Use Committee and used domestic homing pigeons obtained from a local pigeon fancier. The birds were housed in approved cages and fed a commercial pigeon diet and water ad libitum. All the birds were weighed and given a physical examination to determine that they were healthy before the study. Whole-body ventrodorsal (V/D) radiographs were used to evaluate the GI transit times in these pigeons. The right lateral view was obtained if needed to clearly identify the BIPS location. All radiographs were taken without the use of sedation by using a digital radiograph machine (Eklin Medial Systems Inc, Santa Clara, CA, USA) and viewing software (Efilm, Hollywood, CA, USA). The pigeons were fasted for 6 hours before administration of contrast agents, had access to water 30 minutes after initial (time 0) radiographs, and were offered food after 6 hours.

Preliminary trial

Six domestic pigeons were initially obtained for this study. After a 6-hour fast, 1 pigeon was given twenty 1.5-mm-diameter BIPS to determine if and when the particles would pass through specific segments of the bird's GI system (proventriculus, ventriculus, proximal small intestines, and distal large intestine-cloaca), and predict when all of the BIPS should have passed into the distal large intestine-cloaca. An attempt by 1 investigator (J.P.H., unpublished data, 2005) to use BIPS in a cockatiel (*Nymphicus hollandicus*) suspected of being obstructed by a radiolucent foreign body suggested that the capsules would not readily dissolve in the crop and release the spheres. For that reason, in this study, the BIPS were removed from the capsule and suspended in 10 mL of saline solution and were administered by gavage into the crop. Whole-body digital radiographs, V/D and right lateral views, were taken at times 0, 15, 30, 60, 90, 120, 240, and 360 minutes, and at 24 hours.

The 5 remaining birds were randomly selected to receive 1.5-mm BIPS administered by 1 of 5 different methods to determine a suitable method of administration for this study. After the 6-hour fast, the birds received twenty 1.5-mm BIPS by gavage into the crop by 1 of the following methods: 1) suspended in 10 mL of a mixture of 30 mL water with 1 g of a psyllium-based fiber supplement (Metamucil, Proctor & Gamble, Cincinnati, OH, USA), 2) 10 mL of a water-based lubricant (K-Y Jelly, Johnson and Johnson Health Care Systems Inc, Piscataway, NJ, USA), 3) 10 mL of a water and ground commercial poultry food suspension (1 g of food in 30 mL water), 4) 10 mL of 30% barium sulfate suspension, or 5) administered concurrently with commercial whole bird seed as fed. Whole-body V/D view radiographs were taken at the same times as in the first bird for comparison. The birds were released to return home when the BIPS passed from their GI tracts.

BIPS versus barium suspension trial

At the completion of the preliminary trial, when it appeared that suspension in 6 different agents did not influence the rate of passage of BIPS, 6 additional pigeons each underwent 2 treatments (barium sulfate suspension and BIPS). All the birds were fasted for 6 hours before administration of contrast agents.

The first treatment for each bird involved administration of thirty 1.5-mm BIPS in an open-ended, premoistened capsule. Whole-body V/D view radiographs were taken at 0, 15, 30, 60, 90, 120, 240, and 360 minutes, and at 24 hours at a minimum. Radiographs were taken once daily from that point at 24-hour intervals until all BIPS had passed. The birds were then given a washout period of at least 72 hours, during which time they were offered their normal food and water.

The second treatment for each bird involved administration of 10 mL of 30% barium sulfate suspension into the crop by gavage. Whole-body V/D view radiographs were taken at 0, 15, 30, 60, 90, 120, 240, and 360 minutes, and at 24 hours. All of the barium had passed by 24 hours. The birds were released to return home after completing this study.

Data analysis

All analyses were done by using PC SAS Version 9.1 (SAS Institute, Cary, NC, USA). For each chosen organ location in the GI tract (crop, ventriculus, distal large intestine, and cloaca), the percentage arrival of the 30 BIPS administered and the mean and SD for the arrival and passing times for barium and BIPS were calculated. Because of the count nature of the times recorded and the associated heterogeneous nature of the variances, the raw data were transformed before analysis by a natural logarithmic function. The transit times for BIPS and for the 30% barium sulfate suspension in the respective birds were compared by paired t tests. A value of $P \leq .05$ was considered significant and indicated that the 2 treatment means were not equal. Data that involved BIPS were graphed by using Microsoft Windows Office 2003 Excel (Microsoft Corporation, Redmond, WA, USA).

Results

Preliminary trial

The twenty 1.5-mm BIPS suspended in 10 mL of a 0.9% saline solution given to the first bird passed into the ventriculus within 1 hour but failed to go further within the initial allotted sample time of 360 minutes. Additional radiographs were taken at 24 hours and then every 24 hours until the BIPS passed out of the GI tract at 5 days. Lateral and V/D view radiographs proved unnecessary to follow the transit of BIPS through the GI tract (Fig 1), and only V/D view radiographs were obtained in subsequent trials. In the remaining 5 birds, BIPS suspended in water with psyllium, water-based lubricant, 10 mL of barium sulfate suspension, ground seed, or commercial pigeon diet gavaged into the crop similarly passed into the ventriculus within 1 hour. However, some BIPS still remained in the GI tract of all of the pigeons for at least 72 hours regardless of method of administration.

BIPS versus barium suspension trial

No increase in the number or rate of passage of 1.5-mm BIPS was appreciated radiographically when 1.5-mm BIPS were administered in a moistened, open-ended gelatin capsule. The 1.5-mm BIPS in a gelatin capsule passed from the crop into the ventriculus in 30 minutes and remained there for more than 24 hours. BIPS were still seen on daily radiographs of 2 of the 6 pigeons at 13 days (312 hours) after administration, with 1 of these 2 birds maintaining BIPS in the ventriculus beyond 31 days. In contrast, serial radiographs showed that 10 mL of 30% barium sulfate suspension administered into the crop passed through and completely out of the bird's GI tract within 24 hours.

The GI transit times of the thirty 1.5-mm BIPS and the 10 mL of 30% barium sulfate suspension, both administered by gavage into the crop, were compared (Table 1). There was no significant difference between the barium suspension and the BIPS in the time of administration and passage from the crop ($P = .19$) or when reaching the ventriculus ($P = .14$). However, the 1.5-mm BIPS took significantly longer ($P < .001$) than barium sulfate to pass from the ventriculus to the small intestines, to reach the large intestine-cloaca, and then to pass from the large intestine-cloaca. A representative series of whole-body V/D views of a pigeon administered 1.5-mm BIPS and showing retention of the BIPS in the ventriculus is presented in Figure 2. A GI series of whole-body V/D radiographs of a pigeon after 30% barium suspension was administered is presented in Figure 3.

The number of 1.5-mm BIPS increased over time as they reached each digestive organ and then decreased as they passed through the organ and were eliminated. The mean number of 1.5-mm BIPS in the GI tract of the 6 pigeons and the change in the mean over time is shown in Figure 4. The BIPS were rarely seen in the proventriculus and were infrequently seen in the proximal small intestine of the 6 birds. The BIPS were retained in the ventriculus for the greatest amount of time but eventually passed out of the birds and were seen radiographically in the birds' feces. The times for 30% barium sulfate suspension to reach regional anatomic locations in the GI tract of the 6 pigeons are listed in Table 2, along with times reported for 1 variety of domestic pigeon.[5]

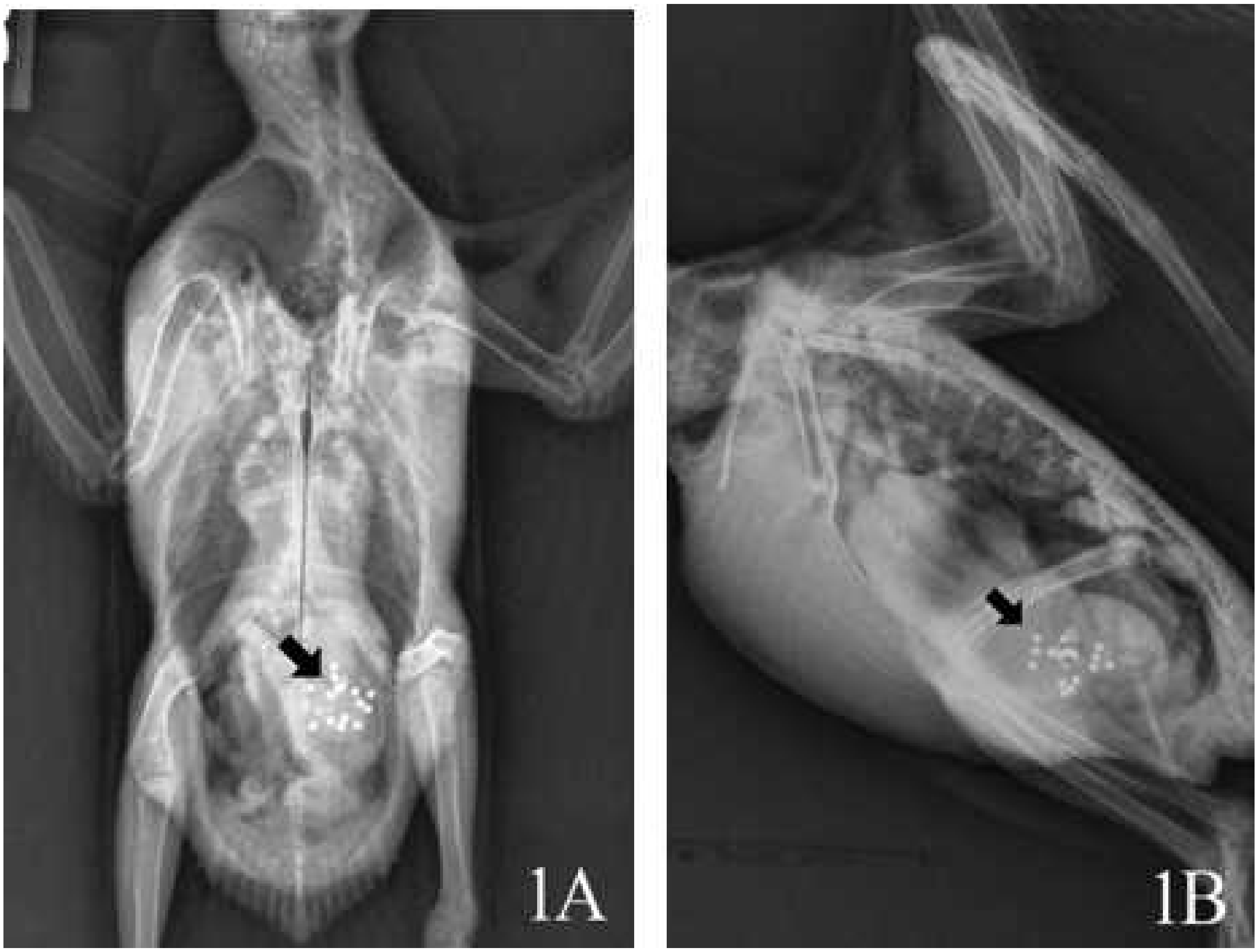

Figure 1. Whole body ventrodorsal (V/D) (A) and right lateral (B) view digital radiographs of a domestic pigeon, showing 1.5-mm barium-impregnated polyethylene spheres (arrow heads) in the ventriculus 90 minutes after administration into the crop by gavage.

Discussion

This study was done to identify the potential use of BIPS in evaluating the avian digestive system. These spheres were designed for use in mammals and offer the potential to determine GI motility by using a particle size that more closely resembles food particles than liquid. From our results, we concluded that BIPS were not suitable for use in birds with a muscular ventriculus, but they may have application in carnivorous avian species. The data we present are a step in the continued efforts to refine and expand diagnostic options in avian species. Possible clinical applications for BIPS might include avian conditions that alter GI motility, such as proventricular dilatation syndrome of large psittacine birds, heavy metal (lead) toxicosis of all birds, or GI

Table 1. Comparison of transit times (mean ± SD) of barium-impregnated polyethylene spheres (BIPS) and 30% barium sulfate suspension in the gastrointestinal tract of 6 domestic pigeons.

Anatomic location	Transit time (h) BIPS	Transit time (h) Barium sulfate	*P* value
Pass crop	14.67 ± 18.18	4.17 ± 1.60	.19
Reach ventriculus	10.67 ± 24.17	0.13 ± 0.14	.14
Pass ventriculus	368.00 ± 176.80	7.00 ± 0.00	<.001
Reach large intestine-cloaca	70.00 ± 54.95	1.42 ± 0.49	<.001
Pass large intestine-cloaca	424.00 ± 204.59	24.00 ± 0.00	<.001

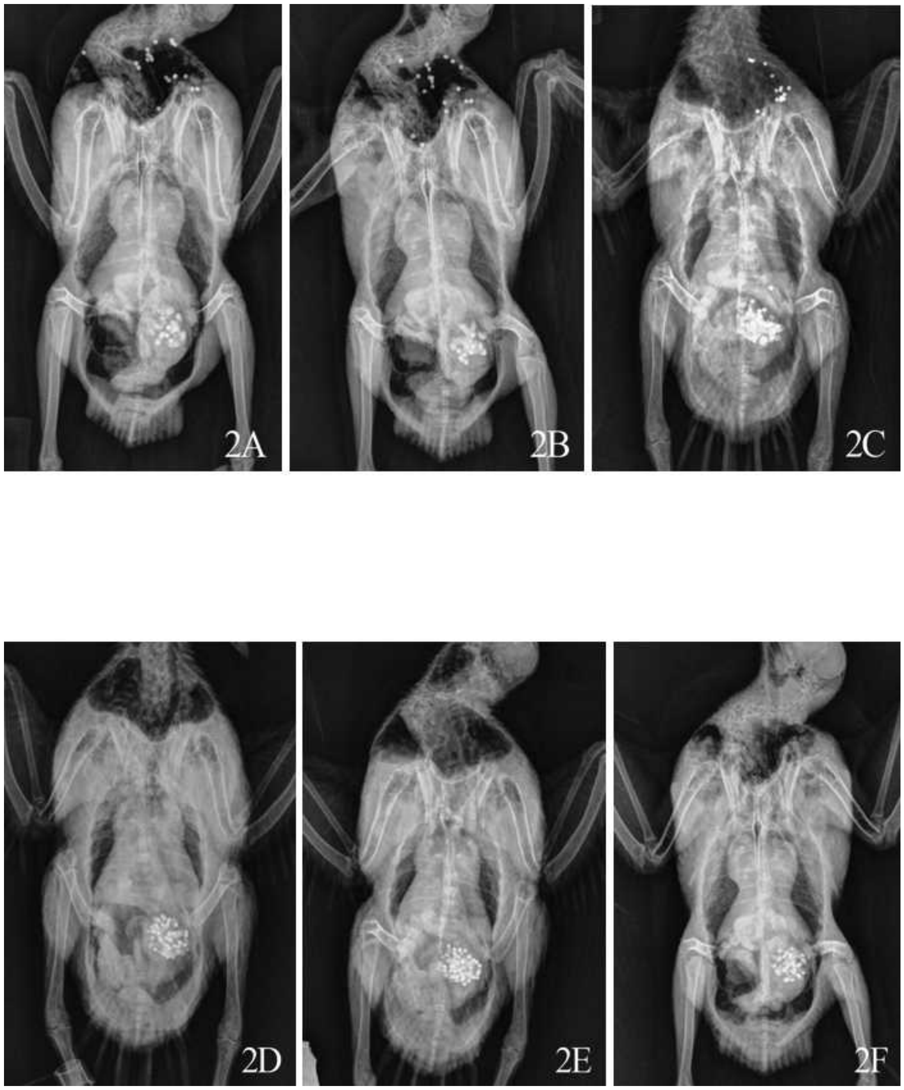

Figure 2. Whole-body ventrodorsal view digital radiographs of a domestic pigeon, showing the 1.5-mm barium-impregnated polyethylene spheres in the ventriculus at 15 minutes (A), 30 minutes (B), 90 minutes (C), 24 hours (D), 48 hours (E), and 9 days (F) after administration into the crop by gavage.

obstructions with radiolucent objects. An additional benefit of using BIPS is that they pose little risk of intra-abdominal contamination in cases of possible GI perforation.

We used GI transit times obtained with barium sulfate suspension as a standard to compare BIPS transit times in the GI tract of domestic pigeons. Our results confirmed that the time intervals for radiographic presence of the 30% barium sulfate suspension in a given GI organ were similar to those reported and considered to be normal for another variety of domestic pigeon.[5] Isoflurane has been used to prevent struggling and motion of birds undergoing a GI series with barium sulfate suspension.[4,5] No sedatives were used in this study to minimize any potential impact on the GI motility of these pigeons.

We elected to use only the 1.5-mm BIPS in this study because BIPS particles of this size are designed to mimic GI transit of ingesta, and we were concerned that the 5-mm BIPS, which are designed to detect obstructions,[6] would be too large for the pigeons to readily pass through the ventriculus and might cause an impaction.

In the initial trials, we established that the 1.5-mm BIPS could be visualized radiographically in the pigeons, even when ingesta was present in the GI tract and that only the V/D view radiographs are necessary to visualize the BIPS. Because the GI structures were less superimposed on the V/D view than on the lateral view and the lateral view proved unnecessary to follow transit through the GI tact (Fig 1), we used the V/D for each series. The orthogonal view (right lateral) was used

Figure 3. Whole-body ventrodorsal view radiographs of a domestic pigeon immediately (A), 15 minutes (B), 30 minutes (C), 90 minutes (D), and 24 hours (E) after administration of 30% barium suspension into the crop by gavage. The arrow head in A represents grit in the ventriculus.

periodically when necessary to determine the location of specific particles but not to measure transit time.

Because prolonged passage of BIPS particles through the ventriculus would preclude evaluation of the GI tract distal to the ventriculus, a preliminary trial was undertaken to investigate alternative methods of BIPS administration. We were initially concerned that the gelatin capsules would not dissolve in the crop in a timely manner to allow release of BIPS. For that reason, BIPS particles were removed from the gelatin capsule and suspended in a 0.9% saline solution. However, BIPS have an affinity for the plastic of the dosing syringe, and it was difficult to administer all of the 1.5-mm particles. Suspending BIPS in psyllium, water-based lubricant, and even barium sulfate suspension did not improve transit time of the particles. Mixing the BIPS with food that the particles were intended to simulate proved unrewarding in improving GI transit. Administering a consistent number of BIPS particles was difficult by any method, which made comparisons at a given location very difficult.

Another concern was that enough particles would be present to help distinguish trends in passage through the GI tract. Administration in a gelatin capsule, as the product is designed, ensures delivery of adequate numbers of particles. Moistening the capsule softened it and allowed for a decrease in capsule size to facilitate administration to birds of the size used in this study. Thirty 1.5-mm BIPS in the moistened, open-ended gelatin capsules were then used for comparison with liquid barium suspension. This method proved to be easier for administration of a

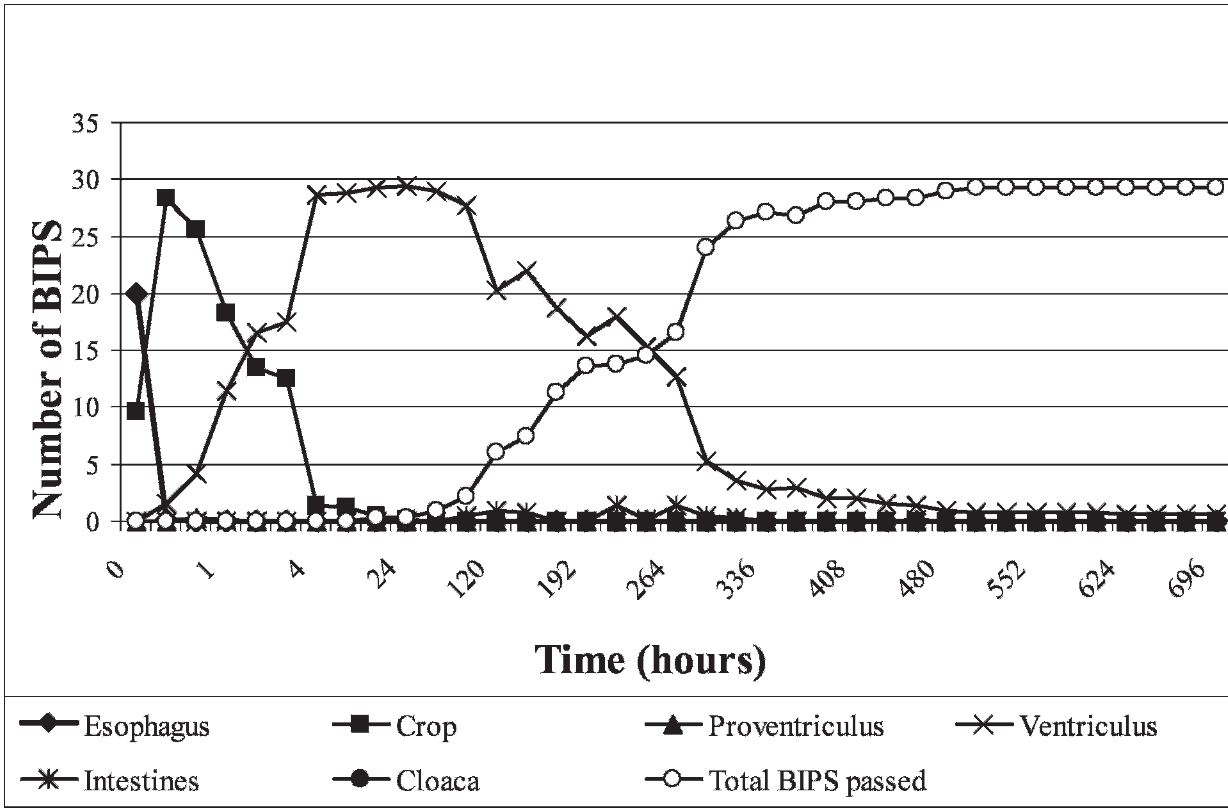

Figure 4. Graph of the mean number of thirty 1.5-mm barium-impregnated polyethylene spheres (BIPS) that were seen radiographically at the respective times in the esophagus, crop, proventriculus, ventriculus, intestines, and cloaca, after administration to 6 domestic pigeons.

consistent and adequate number of BIPS particles to be counted on the serial digital radiographs after administration.

One study design flaw was that administering the intact BIPS gel capsule was not attempted in the initial trial. The capsules are designed to dissolve in the stomach fluids of mammals and release the spheres, but a previous attempt to use the BIPS capsules in a cockatiel suspected of being obstructed indicated that the capsules did not rapidly dissolve in the crop. Our concern was that the intact capsule would not dissolve adequately to release the BIPS particles in a timely manner to perform the study. Given the particle dispersal from BIPS in a moistened and open-ended capsule, administration of BIPS in a premoistened closed capsule might be attempted. This likely would not have changed the results of this study but might facilitate the use of BIPS in other avian species.

Table 2. Transit times (min) to reach locations in the digestive tract of barium sulfate suspension administered by gavage into the crops of 6 domestic pigeons compared with times reported for racing pigeons.[5]

Bird group	Stomach (proventriculus)	Small intestine	Cloaca
Racing pigeon	5–10	10–30	120–240
Study pigeon	0–30	15–30	60–480

The BIPS were not reliable for evaluating passage of food-like materials through the GI tract of this granivorous species. Although both the BIPS particles and the 30% barium sulfate suspension passed the crop and then reached the ventriculus in a similar time period, the times for passing through the ventriculus and for reaching and passing through the large intestine-cloaca were significantly longer for 1.5-mm BIPS than for barium. This difference in transit times can be attributed to the prolonged time that the BIPS particles spent in the ventriculus. Although the size and shape of the 1.5-mm BIPS particles are similar to that of seeds and ground food that pigeons normally ingest, the firm structure of the BIPS particles did not break down with the digestive process and were retained in the ventriculus. Although it is normal for larger food particles to be retained in the ventriculus for long periods of time,[8] we postulated that in pigeons, the BIPS particles act in a manner closer to grit that is normally retained in the muscular ventriculus to aid in the grinding of food rather than as food itself.

The pigeons used in this study did not have a source of grit or gravel to ingest during this investigation, with the exception of any particles that may have been present in the diet. In a few of the study birds, radiopaque grit or gravel was seen in the ventriculus on survey radiographs, but this was readily distinguished from the BIPS, which were perfectly round and more intensely radiopaque than the grit. The mammal species for which BIPS particles were designed and studied have simple stomachs (carnivorous and omnivorous species) or do not retain ingesta in the stomach for prolonged periods of time for processing. The passage of BIPS particles in an avian species that lacks a prominent muscular ventriculus, such as strictly carnivorous species, may more closely resemble normal GI transit times. Retention of grit in species that do not consume seeds appears to be limited to very small particles that are likely to represent inadvertent soil ingestion rather than voluntary consumption of indigestible particles.[9]

Although BIPS can be a useful tool in characterizing GI function radiographically in some mammal species, BIPS were not useful in this study with domestic pigeons. In the GI tract of granivorous avian species, BIPS behave more like gravel or grit than digestible food. Further investigation is needed to determine if BIPS would be useful in avian species that lack a muscular ventriculus.

References

1. Nelson OL, Jergens AE, Miles KG, Christensen WF. Gastric emptying as assessed by barium-impregnated polyethylene spheres in healthy dogs consuming a commercial kibble ration. *J Am Anim Hosp Assoc*. 2001;37:444–452.
2. Hetland H, Svihus B. Effect of oat hulls on performance, gut capacity, and feed passage time in broiler chickens. *Br Poult Sci*. 2001;42:354–361.
3. Nasir A, Moudgal RP, Singh NB. Involvement of corticosterone in food intake, food passage time and in vivo uptake of nutrients in the chicken (*Gallus domesticus*). *Br Poult Sci*. 1999;40:517–522.
4. Smith BJ, Smith SA. Radiology. In: Altman RB, Clubb SL, Dorrestein GM, Quesenberry K, eds. *Avian Medicine and Surgery*. Philadelphia, PA: WB Saunders; 1997:170–199.
5. McMillan MC. Imaging techniques. In: Ritchie BW, Harrison GJ, Harrison LR, eds. *Avian Medicine: Principles and Application*. Lake Worth, FL: Wingers Publishing; 1994:246–326.
6. Robertson ID, Burbridge HM. Pros and cons of barium-impregnated polyethylene spheres in gastrointestinal disease. *Vet Clin North Am Small Anim Pract*. 2000;30:449–465.
7. Campbell JL, Williams CV, Eisemann JH. Characterizing gastrointestinal transit time in four lemur species using barium-impregnated polyethylene spheres (BIPS). *Am J Primatol*. 2004;64:309–321.
8. Vergara P, Ferrando C, Jimenez M, et al. Factors determining gastrointestinal transit time of several markers in the domestic fowl. *Q J Exp Physiol*. 1989;74:867–874.
9. Luttik R, deSnoo GR. Characterization of grit in arable birds to improve pesticide risk assessment. *Ecotoxicol Environ Saf*. 2004;57:319–329.