# Contrast fluoroscopic evaluation of gastrointestinal transit times with and without the use of falconry hoods in red-tailed hawks (*Buteo jamaicensis*)

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**OBJECTIVE**

To evaluate gastrointestinal transit times in red-tailed hawks (*Buteo jamaicensis*) by use of contrast fluoroscopic imaging and investigate the effect of falconry hooding in these hawks on gastrointestinal transit time.

**DESIGN**

Prospective, randomized, blinded, complete crossover study.

**ANIMALS**

9 healthy red-tailed hawks.

**PROCEDURES**

Hawks were gavage-fed a 30% weight-by-volume barium suspension (25 mL/kg [11.3 mL/lb]) into the crop. Fluoroscopic images were obtained at multiple time points after barium administration. Time to filling and emptying of various gastrointestinal tract organs and overall transit time were measured. The effect of hooding (hooded vs nonhooded) on these variables was assessed in a randomized complete crossover design.

**RESULTS**

In nonhooded birds, overall gastrointestinal transit time ranged from 30 to 180 minutes (mean ± SD, 100 ± 52 min). Time to complete crop emptying ranged from 30 to 180 minutes (83 ± 49 min). Contrast medium was present in the ventriculus in all birds within 5 minutes of administration and in the small intestines within 5 to 15 minutes (median, 5 min). Hooding of red-tailed hawks resulted in a significant delay of complete crop emptying (no hood, 83 ± 49 minutes; hood, 133 ± 48 minutes), but no significant effects of hooding were found on other measured variables.

**CONCLUSIONS AND CLINICAL RELEVANCE**

These results indicated that overall gastrointestinal transit times are faster in red-tailed hawks than has been reported for psittacines and that the use of a falconry hood in red-tailed hawks may result in delayed crop emptying. Hooding did not exert significant effects on overall gastrointestinal transit time in this raptorial species. (*J Am Vet Med Assoc* 2017;251:1064–1069)

Positive-contrast studies are common diagnostic tools for evaluating the gastrointestinal tract in birds and are often used to identify foreign bodies, luminal defects, and intracoelomic masses.[1-3] Additionally, the gastric cycle and filling and clearance of contrast medium from individual organs as well as overall gastrointestinal transit time can be assessed, assisting with the diagnosis of motility disorders. Changes in motility can be observed with many pathological processes, including heavy metal intoxication, gastrointestinal parasitism, and inflammation.[1] Positive-contrast medium is typically administered via gavage to reduce the risk of aspiration, and radiographic exposures are taken at various time points to assess target organs or follow progression of medium through the gastrointestinal tract. Although manual restraint or chemical immobilization has been used to perform radiographic contrast studies with traditional radiography techniques, both stress and anesthetics have been noted as potentially influencing results in avian species.[1,4–6] Offering several advantages over analog contrast radiography techniques, contrast fluoroscopy has become commonplace in avian medicine and is considered the standard for evaluating gastrointestinal peristalsis.[1,4,5,7]

Most research evaluating gastrointestinal transit time in birds has involved psittacines,[4,5,7] but a few prospective studies in other avian orders have been performed.[8–10] Almost all the values for transit times in birds of prey are anecdotal in nature.[1,3,11–13] A literature search revealed few peer-reviewed studies assessing gastrointestinal transit time in birds of prey.[14,15] The lack of defined reference intervals for overall and specific alimentary organ gastrointestinal transit times in many avian species makes objective evaluation of motility problematic. Despite their popularity in falconry and frequency as wildlife patients in North America, little is known about the gastrointestinal transit time of the red-tailed hawk (*Buteo jamaicensis*) or other members of the order Accipitriformes.

Falconry hoods have been used for hundreds of years by falconers as a means of calming newly acquired raptorial birds during training.[16] Hooded birds are often remarkably calm,[17] even when hooded for the first time. Because of this effect, hooding is often used to transport and handle birds of prey as well as to facilitate diagnostic and therapeutic procedures in a clinical setting.[17–19] Hooding has been specifically used to facilitate contrast radiographic and fluoroscopic imaging studies in both ostriches and birds of prey.[9,20] Use of a falconry hood has the potential to notably facilitate the process of fluoroscopy in raptorial birds. Fluoroscopic image acquisition is subjectively simple when a bird is positioned on a moveable, freestanding perch. However, many wild birds of prey will not remain on a fixed perch in a nonenclosed space without being hooded. Interestingly, birds of prey seem to defecate less frequently when wearing a falconry hood; it is possible that this observation translates into extended gastrointestinal transit times. Although the use of a hood often results in less agitation for the bird, its effect on gastrointestinal transit time is unknown.

The objectives of the present study were to evaluate gastrointestinal transit time in red-tailed hawks by use of contrast fluoroscopy and to investigate whether hooding has any effect on transit time in this species. We hypothesized that overall gastrointestinal transit time would be similar to anecdotal reports for birds of prey and that hooding would increase overall gastrointestinal transit time.

## Materials and Methods

### Population studied

Red-tailed hawks (n = 9) that were estimated to be at least 2 years of age on the basis of plumage and were of undetermined sex were used for this study. The birds were systemically healthy, free-ranging animals undergoing rehabilitation at wildlife centers. Only hawks at the end of the rehabilitation process that were considered clinically normal were included in the study. All birds underwent physical examinations and were considered to be in good health for the duration of the experimental trials. All animals were fecal parasite negative by direct smear and flotation methods, and none had clinical signs of gastrointestinal disease at the time the research was performed. Animals were housed at their respective institutions and were maintained on diets consisting of frozen-thawed mice. Food was withheld from the animals for 12 to 18 hours prior to the experiments, and the animals were transported to the University of Wisconsin School of Veterinary Medicine on the day of each experiment. All procedures were approved by the Institutional Animal Care and Use Committee of the School of Veterinary Medicine, University of Wisconsin.

### Study design

The effect of hooding on gastrointestinal transit times, as well as on filling and emptying of various gastrointestinal organs, was evaluated by use of a randomized, blinded, complete crossover experimental design. For hooded trials, a leather falconry hood (Rollins; size, 64 mm) recommended for use in either male or female red-tailed hawks was used. A minimum of 6 days was allotted between trials. All radiographic views were examined by a single, board-certified radiologist (JMW) who was blinded to whether the birds were hooded.

### Fluoroscopic image acquisition

Raptors were placed in specially constructed enclosures **(Figure 1)** made from opaque, white, corrugated plastic sheets with a semitranslucent sliding front-access door made from acrylic material.[a] These containers were constructed to allow light transmission so animals would be able to perceive ambient light. Fixed perches appropriately sized for a medium-sized raptorial bird species were located within the boxes. Ambient room temperature was maintained from 22° to 24°C (71° to 75°F).

Right lateral and ventrodorsal survey fluoroscopic images were obtained by use of a commercial C-arm


**Figure 1**—Photograph of a red-tailed hawk (*Buteo jamaicensis*) wearing a falconry hood while housed in a specially designed chamber constructed to facilitate obtaining a contrast fluoroscopic series. The hawk is positioned for a ventrodorsal fluoroscopic exposure. A sliding acrylic door has been removed from the front of the chamber for the photograph.

unit[b] while the birds were kept in the fluoroscopic chambers (Figure 1) prior to administration of contrast medium. Hawks were manually restrained and then gavage-fed a 30% weight-by-volume barium suspension[c] (25 mL/kg [11.3 mL/lb]) into the crop with a 14F to 16F feeding tube.[d] Paired right lateral and ventrodorsal fluoroscopic still images were obtained at 5-, 15-, 30-, 45-, 60-, 90-, 120-, 180-, 240-, and 300-minute time points after barium administration. At the 30-, 60-, 120-, and 240-minute time points, 60 seconds of video (2 to 15 frames/s) was captured in the right lateral view to assess gastrointestinal peristalsis. The frequency of contractions of the ventriculus was calculated via available fluoroscopic video clips.

Overall gastrointestinal transit time was defined as time to presence of contrast medium within the caudal aspect of the rectum **(Figure 2)**. Crop emptying time was defined as the absence of all contrast medium within the crop on both the lateral and ventrodorsal views. Gastric emptying time was defined as the absence of contrast medium within the proventriculus and ventriculus on both fluoroscopic views or the presence of a small enough amount of material to highlight the rugal folds only.

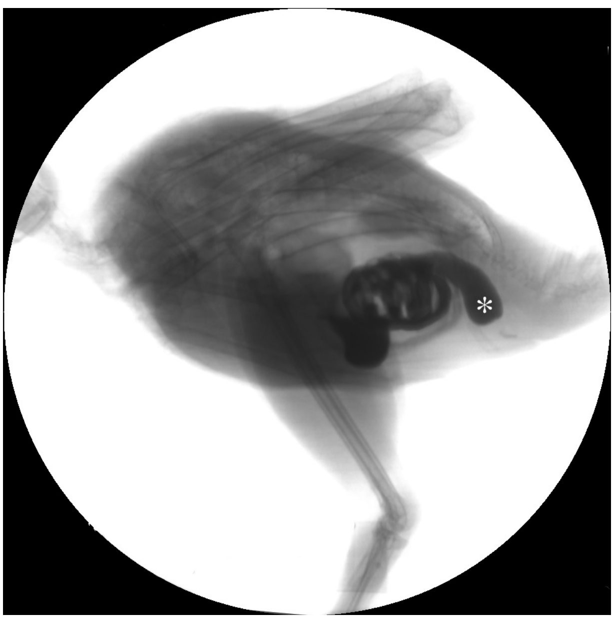

**Figure 2**—Right lateral fluoroscopic still image of a red-tailed hawk undergoing a gastrointestinal contrast study. The head of the bird points to the left, whereas the tail points to the right. Contrast medium has reached and filled the caudal aspect of the rectum (asterisk).

### Statistical analysis

Data were analyzed with a commercial statistical software package.[e] Data were tested for normality by means of a Shapiro-Wilk test and, when applicable, for constant variance by means of a residual versus fitted value plot. Data were analyzed for effects of hooding on gastrointestinal filling and emptying times by use of a paired 2-tailed Student $t$ test for normally distributed data or otherwise a Wilcoxon signed rank test. Frequency of contractions of the ventriculus at different time points was compared by means of a repeated-measures ANOVA. The Holm-Sidak method was used for post hoc pairwise multicomparison procedures. Values of $P < 0.05$ were considered significant. Data are reported as mean ± SD and range if normally distributed and as median and range for nonnormally distributed data.

## Results

The mean ± SD body weight of the red-tailed hawks was 1.30 ± 0.16 kg (2.92 ± 0.36 lb). Fluoroscopic findings were summarized **(Table 1)**. In nonhooded birds, overall transit time ranged from 30 to 180 minutes (mean, 100 ± 52 minutes). In nonhooded birds, time to complete crop emptying ranged from 30 to 180 minutes (mean, 83 ± 49 minutes). Contrast medium was present in the ventriculus in all birds within 5 minutes of administration and in the small intestines within 5 to 15 minutes (median, 5 minutes). Barium contrast medium was rarely observed within the proventriculus and was in most instances located only within the ventriculus following crop contraction. Interestingly, in video captured from a ventrodorsal view in 1 hawk, contrast medium was observed moving rapidly from the crop into the proventriculus, then filling the ventriculus following

**Table 1**—Temporal gastrointestinal transit times (minutes) in 9 red-tailed hawks (*Buteo jamaicensis*) evaluated by use of fluoroscopic imaging with and without the use of a falconry hood.

| | No hood | | | Hood | | |
|---|---|---|---|---|---|---|
| **Variable** | **Mean ± SD** | **Median** | **Range** | **Mean ± SD** | **Median** | **Range** |
| Overall transit time* | 100 ± 52 | — | 30 to 180 | 110 ± 37 | — | 60 to 180 |
| Ventriculus† | 5 ± 0 | — | None | 5 ± 0 | — | None |
| Small intestine† | — | 5 | 5 to 15 | — | 5 | 5 to 15 |
| Complete crop emptying | 83 ± 49‡ | — | 30 to 180 | 133 ± 48‡ | — | 60 to 180 |
| Ventriculus emptying | — | — | 240 to > 300 | — | — | 240 to > 300 |

Mean ± SD values are provided for parametric data. Median values are provided for nonparametric data.

*Time to presence of contrast medium in the caudal portion of the rectum. †Time to initial filling of organ with contrast medium. ‡Significant ($P < 0.05$) difference in mean ± SD values between a bird not wearing a falconry hood and wearing a falconry hood.

— = Not applicable.

opening of the gastric isthmus (**Supplementary Video S1**, available at avmajournals.avma.org/doi/suppl/10.2460/javma.251.9.1064).

Contractions of the ventriculus (**Supplementary Video S2**, available at avmajournals.avma.org/doi/suppl/10.2460/javma.251.9.1064) were observed in all birds. Video captured in the right lateral view showed rotating distortion of the ventricular wall, which varied from slow to rapid in speed. The number of contractions of the ventriculus decreased substantially over time, and contractions were most frequent from 30 to 120 minutes after gavage (range, 0 to 3 contractions/min). The lowest number of contractions was seen at 240 minutes (range, 0 to 1 contractions/min). The number of contractions of the ventriculus in nonhooded hawks was significantly ($P < 0.05$) higher at 30 and 60 minutes ($1.5 \pm 0.9$ and $1.4 \pm 1.1$ contractions/min, respectively), compared with at 240 minutes ($0.3 \pm 0.5$ contractions/min), after barium administration. Almost constant peristalsis of the small and large intestines was observed in all birds during fluoroscopic examination, indicating gastrointestinal motility in all hawks. Because of the superimposition of intestinal loops and imaging technique, it was difficult to determine whether these peristaltic waves were anterograde or retrograde in nature. In 1 bird, discernible reflux of contrast medium from the proximal portion of the duodenum into the ventriculus was observed in 1 video clip during 1 trial, which was suspected to be consistent with retrograde peristalsis. Rapid, dynamic sacculation of the rectum was appreciated on the right lateral view in the hawks and was suspected to be indicative of antiperistalsis.[6]

Gastric emptying of contrast medium was not complete in 6 of 9 hawks by 300 minutes after administration of contrast medium. Time to presence within the cloaca in this population of hawks could not be reliably recorded in most birds, as defecation appeared to occur rapidly following peristalsis of the rectum and barium was not held within the cloaca for a long enough time. The filling and emptying times of the large intestines could not be interpreted reliably (with the exception of the caudal aspect of the rectum) as a result of superimposition of other soft tissue structures within the images and were not reported.

Hooding of red-tailed hawks resulted in a significant ($P = 0.02$) delay of complete crop emptying (hooded, $133 \pm 48$ minutes [60 to 180 minutes]; nonhooded, $83 \pm 49$ minutes [30 to 180 minutes]). With the exception of the crop emptying time, hooding had no significant effect on gastrointestinal filling and emptying times. Although not statistically significant, the overall transit time was 1.33 to 2 times as long in 6 of 9 hawks with hoods, compared with hawks without hoods. There was a nonsignificant ($P = 0.12$) decrease in number of contractions of the ventriculus at 120 minutes in hooded birds (median, 0.5 contractions/min; range, 0 to 1 contractions/min), compared with nonhooded birds (median, 1.0 contractions/min; range, 0 to 3 contractions/min).

By the end of the fluoroscopic studies (300 minutes after barium administration), total clearance of contrast medium from either the small intestines or rectum had not occurred in any hawk, regardless of whether it was hooded or not.

## Discussion

The fluoroscopic findings in the population of red-tailed hawks in the present study were similar to existing anecdotal reports in the veterinary medical literature. Similar to other avian species,[5,20] the transit time of contrast medium through various gastrointestinal organs was highly variable between individual red-tailed hawks.

The rapid filling of the proventriculus and ventriculus following administration of the contrast medium in the red-tailed hawks of the present report was similar to that found in previous anecdotal reports for birds of prey.[1,3,11,12,15,20] However, although time to small intestinal filling in the present study was similar to some others,[1,3,15,20] it was slightly faster than a few of the existing values.[11,12] This discrepancy may be the result of differences in study procedures. Similarly, comparisons of the overall gastrointestinal transit time in this population with other published reports in birds of prey are challenging because of insufficient information or differing methods. Most published data are reported in ranges in tabulated form only, and mean or median values are not available.[1,3,11,12] Also, few studies report their definition[5] of overall gastrointestinal transit time but rather report time to presence of contrast within or emptying of contrast from various organs.[1,3,11,12,20]

In general, transit times for various gastrointestinal organs are reported to be faster in birds of prey than in psittacine species.[1,4,11,13] Time to presence of contrast within the ventriculus and small intestines in the population of hawks of the present study was either similar to[5] or faster than[1,4] values previously reported for psittacines. However, overall gastrointestinal transit time appeared to be faster in our population of nonhooded red-tailed hawks, compared with that of other avian orders. In a study[5] in Congo African grey parrots (*Psittacus erithacus*; n = 8), mean overall gastrointestinal transit time was approximately 3 times the mean time recorded in the present study. Similarly, the time taken for contrast to reach the terminal aspect of the gastrointestinal tract in ostriches[9] was substantially longer than the mean overall transit times reported in the present study. These differences are expected and likely the result of distinctions in size or feeding and digestive strategies.[7] For example, the ventriculus of psittacine birds is more suited for processing of hard foods, such as nuts or seeds, whereas raptors have a predominantly carnivorous diet and a relatively simple gastrointestinal tract with overall faster processing times than noncarnivorous birds.[21]

By 300 minutes, most of the 9 birds in the present study (6 when not hooded and 5 when hooded) had not completely cleared contrast medium from the ventriculus. Additionally, by this time point, none of the birds (nonhooded and hooded) had completely cleared the contrast medium from the small intestines or rectum. In a study[20] of medium- to large-sized birds of the *Falco* genus, a few animals maintained contrast in the ventriculus 8 hours after administration; additionally at this time point, contrast medium was still present within the small intestines and cloaca in at least half the falcons. However, in a small falcon species, the American kestrel (*Falco sparverius*), ventricular emptying of contrast occurred in < 15 minutes in 1 bird.[14] In a study on the southern crested caracara (*Caracara plancus*; n = 6), another species in the family Falconidae, ventricular emptying times ranged from 340 to 700 minutes.[15] Further research is needed to evaluate contrast clearance times for these organs in red-tailed hawks and other members of the family Accipitridae.

Contrast material was rarely identified in the cloaca of birds in the present study. It is plausible that retention of material within the cloaca did occur, but was simply missed because of the frequency of the image recording in this experiment. The act of defecation in birds is rapid, with strong aboral contractions of the rectum resulting in evacuation of material within seconds.[6] In a study,[14] kestrels held material in the cloaca for approximately 1 second prior to expulsion.

Contractions of the ventriculus were observed in all hawks in the present study. Similar contractions have been reported in other birds of prey.[14,21,22] The frequency of contractions for this population of red-tailed hawks when not hooded (0 to 3 contractions/min) was comparable to previously reported values (0.91 contractions/min) for this species.[23] The frequency of contractions in our nonhooded hawks was less than that reported for Hispaniolan Amazon parrots.[7] However, use of a semisolid contrast medium in the aforementioned study and dissimilarities in gastric function between parrots and birds of prey may account for the differences seen in this study.

Overall, contraction frequency appeared to decrease over time in the population of nonhooded red-tailed hawks in the present study. One potential explanation is that clearance of the contrast medium from the ventriculus over time resulted in a decreased frequency of contractions. In kestrels administered barium, frequency of gastric contractions decreased over time as the contrast medium was emptied from the proximal portion of the gastrointestinal tract.[14]

Although contractions of the proventriculus were not readily appreciated in the present study, this may have been the result of the use of a liquid, rather than a semisolid or solid, contrast medium and the fact that video was recorded intermittently during the contrast series. In great horned owls, swallowed mice were stored in the proventriculus prior to opening of the isthmus, contraction of the proventriculus, and deposition of the prey into the ventriculus.[22]

Use of a falconry hood in our red-tailed hawks resulted in a significant delay in crop emptying time. Hooding did not have a significant effect on overall gastrointestinal transit time in this raptorial species. Factors including size, diet, and health have been reported to influence the passage of gastrointestinal contents.[1,5,6,9] Delayed overall gastrointestinal transit time can also result from ileus or gastrointestinal inflammation.[1] Causes for delayed crop emptying include primary crop disorders, distal gastrointestinal disease, lead intoxication, or other systemic illness.[24] Because the hawks in the present study had no evidence of gastrointestinal or systemic disease and were of similar weights and husbandry practices, these possibilities seem implausible as the reason for decreased overall transit and crop emptying times in the hooded population. It is possible that hooded hawks may have experienced less stress than when they were nonhooded, simply as a result of lessened audiovisual stimulation, and may have had different transit times as a result. Although the experimental design of the present study attempted to minimize stress during the trials by eliminating handling of the hawks and providing an opaque visual barrier on the fluoroscopic chamber, total prevention of audiovisual stimulation was not possible.

It has been demonstrated that both auditory and visual stimuli have an effect on gastrointestinal motility in red-tailed hawks. In a study,[25] hawks kept in soundproof rooms had longer meal-to-pellet intervals, compared with birds housed in normal surroundings, and light cycle appeared to have some effect on gastrointestinal function. It is possible that some restriction of light and sound from the falconer's hood in this experiment may have affected the gastrointestinal transit times in the birds when hooded.

Rhythmic oscillating or migrating motor complexes within the avian small intestinal tract help birds glean the most from an already consumed meal, especially during times that food is withheld, by instigating both orad and aborad intestinal contractions simultaneously.[6,26] These impulses are also believed to occur at night and during times that food is withheld, secondary to decreased food intake.[26] It is possible that hooding simulated nighttime in this population of diurnal raptors, which led to longer gastrointestinal transit times. Withholding food from this population for the experimental trials may have also led to prolonged retention of contrast medium secondary to increased recycling motor events.[26] However, these motor complexes are best understood in avian species with dramatically different feeding strategies than birds of prey and were not observed in another raptorial bird, the barred owl (*Strix varia*).[26]

Although the hawks in the present study were not clinically dehydrated, withholding of food prior to the experimental trials may have resulted in prolonged retention of gastrointestinal contents within the distal portion of the gastrointestinal tract in order for increased absorption of water and electrolytes.[6,21]

One limitation of the present study was the use of a liquid contrast medium for the fluoroscopic studies. In theory, a liquid food item could be processed or handled by the gastrointestinal tract differently than whole prey or solid foodstuff, especially in a species that normally eats solid prey items. However, the goal of this study was to reproduce a diagnostic contrast series, and the design used materials readily available in a clinical setting. Further research is needed to evaluate the effects of contrast medium consistency on gastrointestinal transit times in birds of prey.

Contrast fluoroscopy appeared to be a safe, easily performed diagnostic tool in red-tailed hawks. Transit times for various gastrointestinal organs and overall gastrointestinal transit time in this species are similar to existing anecdotal information for birds of prey. Although initial filling of the ventriculus and small intestines was rapid, emptying of these organs was not complete by 5 hours. Clinical judgment is needed when fluoroscopic transit data are interpreted in red-tailed hawks wearing falconry hoods, as use of a hood was shown to result in significant delays in crop emptying.

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## Footnotes

a. Optix, Plaskolite Inc, Columbus, Ohio.
b. OEC 8900 C-arm, General Electric, Fairfield, Conn.
c. Liquid E-Z-Paque, E-Z-EM Inc, Lake Success, NY.
d. Rob-Nel catheter, Kendall, Mansfield, Mass.
e. SigmaPlot, version 12.5, Access Softek, Berkeley, Calif.

## References


1. McMillan M. Imaging techniques. In: Ritchie B, Harrison G, Harrison L, eds. *Avian medicine, principles and application.* Lake Worth, Fla: Wingers Publishing Inc, 1994;256–259.
2. Ernst S, Goggin JM, Biller DS, et al. Comparison of iohexol and barium sulfate as gastrointestinal contrast media in mid-sized psittacine birds. *J Avian Med Surg* 1998;12:16–20.
3. Krautwald-Junghanns M, Schroff S, Bartels T. Birds. In: Krautwald-Junghanns M, Pees M, Reese S, eds. *Diagnostic imaging of exotic pets.* Hannover, Germany: Schlütersche, 2011;1–142.
4. Vink-Nooteboom M, Lumeij J, Wolvekamp W. Radiography and image-intensified fluoroscopy of barium passage through the gastrointestinal tract in six healthy Amazon parrots (*Amazona aestiva*). *Vet Radiol Ultrasound* 2003;44:43–48.
5. Kubiak M, Forbes NA. Fluoroscopic evaluation of gastrointestinal transit time in African grey parrots. *Vet Rec* 2012;171:563.
6. Denbow DM. Gastrointestinal anatomy and physiology. In: Scanes CG, ed. *Sturkie's avian physiology.* 6th ed. Waltham: Academic Press, 2015;337–366.
7. Beaufrère H, Nevarez J, Taylor WM, et al. Fluoroscopic study of the normal gastrointestinal motility and measurements in the Hispaniolan Amazon parrot (*Amazona ventralis*). *Vet Radiol Ultrasound* 2010;51:441–446.
8. Macedo J, Silva M, Luiz A, et al. Evaluation of gastrointestinal tract transit times using barium sulfate suspension in toco toucan (*Ramphastos toco*). *Rev Bras Cienc Vet* 2012;19:42–45.
9. Wagner WM, Kirberger RM. Radiographic gastrointestinal contrast study in the ostrich (*Struthio camelus*). *Vet Radiol Ultrasound* 2003;44:546–552.
10. Bloch RA, Cronin K, Hoover JP, et al. Evaluation of gastrointestinal tract transit times using barium-impregnated polyethylene spheres and barium sulfate suspension in a domestic pigeon (*Columbia livia*) model. *J Avian Med Surg* 2010;24:1–8.
11. Smith B, Smith S. Radiology. In: Altman R, Clubb S, Dorrestein G, eds. *Avian medicine and surgery.* Philadelphia: WB Saunders Co, 1997;170–199.
12. Pees M. Radiography. In: Chitty J, Lierz M, eds. *BSAVA manual of raptors, pigeons and passerine birds.* Gloucester, England: British Small Animal Veterinary Association, 2008;114–120.
13. Rubel G, Isenbugel E, Wolvekamp P, eds. *Atlas of diagnostic radiology of exotic pets.* Philadelphia: WB Saunders Co, 1991.
14. Duke G, Reynhout J, Tereick A, et al. Gastrointestinal morphology and motility in American kestrels receiving high or low fat diets. *Condor* 1997;99:123–131.
15. Santos A, Silva J, Kaminishi A, et al. Evaluation of gastrointestinal tract transit times using barium sulfate suspension in *Caracara plancus. PUBVET* 2011;5.
16. Harting J. *Bibliotheca Accipitraria: a catalogue of books ancient and modern relating to falconry, with notes, glossary, and vocabulary.* London: B. Quaritch, 1891.
17. Joseph V. Raptor medicine: an approach to wild, falconry, and educational birds of prey. *Vet Clin North Am Exot Anim Pract* 2006;9:321–345.
18. Cooper JE. Methods of investigation and treatment. In: Cooper JE, ed. *Birds of prey: health and disease.* 3rd ed. Malden, Mass: Wiley-Blackwell, 2002;28–70.
19. Lacasse C. Falconiformes (falcons, hawks, eagles, kites, harriers, buzzards, ospreys, caracaras, secretary birds, Old World and New World vultures). In: Miller RE, Fowler ME, eds. *Fowler's zoo and wild animal medicine.* 8th ed. St Louis: Elsevier-Saunders, 2014;127–142.
20. García Martínez C, Bailey T, Di Somma A. Radiography and image-intensified fluoroscopy of barium passage through the gastrointestinal tract of falcons. *Falco* 2009;19–21.
21. Murray M. Raptor gastroenterology. *Vet Clin North Am Exot Anim Pract* 2014;17:211–234.
22. Rhoades D, Duke GE. Cineradiographic studies of gastric motility in the great horned owl (*Bubo virginianus*). *Condor* 1977;79:328–334.
23. Duke GE, Chaplin SB, Hunt H, et al. The influence of avian pancreatic polypeptide on gastric secretion and motility in red-tailed hawks (*Buteo jamaicensis*). *Comp Biochem Physiol C Comp Pharmacol* 1988;90:231–235.
24. Flammer K, Clubb S. Neonatology. In: Ritchie B, Harrison G, Harrison L, eds. *Avian medicine, principles and application.* Lake Worth, Fla: Wingers Publishing Inc, 1994;805–839.
25. Fuller MR, Duke GE, Eskedahl DL. Regulation of pellet egestion: the influence of feeding time and soundproof conditions on meal to pellet intervals of red-tailed hawks. *Comp Biochem Physiol A Physiol* 1979;62:433–437.
26. Clench M, Mathias J. Intestinal transit: how can it be delayed long enough for birds to act as long-distance dispersal agents? *Auk* 1992;109:933–936.