RADIOGRAPHIC GASTROINTESTINAL CONTRAST STUDY IN THE OSTRICH (*STRUTHIO CAMELUS*)

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Ten gastrointestinal contrast studies were performed with barium on seven clinically healthy ostriches. Concentrations of 25–100% w/vol liquid barium sulfate at 7 and 10 ml/kg were administered by stomach tube after withholding food for 16 h. A 6-frame technique for left-to-right lateral views in standing and a 3-frame technique for the dorsoventral views in sternally recumbent adult ostriches were used for survey and contrast radiographs. Objectives were to describe the appearance of the normal gastrointestinal tract with contrast radiography and to provide a guideline for optimal dosage and concentration of barium sulfate as well as a reliable protocol for frequency of radiographs. Structures that were consistently identified included the esophagus, proventriculus, ventriculus, duodenum, jejunum, proximal, and distal rectum. Due to the superimposition of the remainder of the small intestine, individual components were difficult to differentiate. The caeca were inconsistently highlighted and only for a short time. The ventral pouch of the coprodeum never filled with contrast medium. *Veterinary Radiology & Ultrasound, Vol. 44, No. 5, 2003, pp 546–552.*

Key words: radiography, ratites, *Struthio camelus*, ostriches, anatomy, contrast, barium sulfate, gastrointestinal.

Introduction

In the early 1980s the limits of radiography to diagnose coelomic cavity abnormalities in pet birds was recognized, and contrast studies were added as a tool for avian diagnostics.[1,2] The use of gastrointestinal contrast media can be helpful in identifying normal and pathologic gastrointestinal structures, and allows differentiation of the gastrointestinal from other normal or abnormal internal organs, including reproductive tract associated structures.

Contrast media used in mammals are considered safe in birds,[2] and micropulverized barium sulfate suspension is most frequently used for avian gastrointestinal studies.[3] It can provide excellent visibility of individual structures and mucosal detail.[4] Its use is contraindicated in patients with suspected gastrointestinal perforation and may cause constipation in dehydrated animals.[1] Thus, adequate hydration of the patient should be ensured as well as administering oral fluids after completing the examination.[1]

In pet birds, a range of dosages (25–50 ml/kg) and concentrations (25–50% w/vol) of barium sulfate is used with standard radiographic views (left-to-right lateral and ventrodorsal). Radiographs are routinely obtained before contrast medium administration, immediately after administration, and then at 30 min intervals until the contrast medium has reached the cloaca.[1–3]

Gastrointestinal transit time in seed-eating birds is longer than in other avian species and has been reported to be 30–36 h in ostriches (*Struthio camelus*).[5,6] Other variables that influence transit time in birds are species, nutrition, age, gender, size, hydration status, and diseases.[2] In addition, tranquilizers, anesthetics, and anticholinergics[2] as well as the type, concentration, and volume of contrast medium can all have an effect on transit time. These factors as well as the study objectives will influence the choice of contrast medium, dosage, concentration, and radiographic time intervals. To the best of the authors' knowledge there has been no work published concerning gastrointestinal contrast studies in the ostrich, or ratites in general.

In a previous study[7] the authors were able to provide a detailed radiographic atlas of the normal coelomic viscera in the ostrich. On survey radiographs the esophagus, proventriculus, ventriculus (because of luminal stones), and part of the cloaca could be identified consistently. Using detailed anatomic knowledge, identification of additional individual intestinal loops was inconsistently possible.

The purpose of this study was to describe the normal gastrointestinal appearance of the ostrich with contrast ra-

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TABLE 1. Gastrointestinal Contrast Studies Performed in Ostriches.

No.	Ostrich	Age	Weight	Dosage	Concentration
1	Chick 1	4 Weeks	4 kg	10 ml/kg	50% w/vol
2	Chick 2	4 Weeks	4.06 kg	10 ml/kg	100% w/vol
3	Chick 3	7 Weeks	7.52 kg	10 ml/kg	25% w/vol
4	Chick 4	19 Weeks	30 kg	10 ml/kg	50% w/vol
5	Chick 4	20 Weeks	34 kg	10 ml/kg	25% w/vol
6	Adult 1	3 Years	114 kg	10 ml/kg	25% w/vol
7	Adult 1	3 Years	114 kg	7 ml/kg	50% w/vol
8	Adult 2	3 Years	102 kg	7 ml/kg	50% w/vol
9	Adult 3	13.5 Months	78 kg	7 ml/kg	25% w/vol
10	Adult 3	14 Months	78 kg	7 ml/kg	50% w/vol

diography and to develop a guideline for optimal liquid barium sulfate dosage and concentration as well as radiographic time intervals.

Materials and Methods

Ten contrast studies (Table 1) were performed on seven clinically healthy ostriches ranging from 4 weeks to 3 years in age. Radiographic examination was performed as described previously[8] using a 6-frame technique for left-to-right lateral views in standing and a 3-frame technique for the dorsoventral (DV) views in sternally recumbent adult ostriches. Ostrich chicks had whole body radiographs made (left-to-right in lateral recumbency and DV views in sternal recumbency).[8] Exposure factors were selected from the described technique chart.[8] Dorsovental views of adults could only be obtained in cooperative ostriches. Food was withheld from all ostriches (average 16 h in adults), but free access to water was provided until 1.5 h before the study. No sedation or anesthesia was necessary. Handling time was kept to a minimum during contrast medium administration to minimize stress. This was facilitated by hooding the ostriches and restraining them manually with the occasional use of stocks. Survey radiographs were obtained for those parts of the coelomic cavity containing the digestive tract (craniodorsal (D1), midventral (V2), and caudoventral (V3) views).[8] The studies were started between 8–9 AM.

Ostriches were administered dosages of 7 and 10 ml of contrast medium/kg body weight and concentrations of liquid barium sulfate* from 25–100% w/vol by stomach tube into the distal quarter of the esophagus. Radiographs were made immediately, then at certain intervals for up to 29 h. Access to water was allowed 3 h post barium administration and to food 3 h later.

Gastrointestinal structures were identified and described. Times of appearance of contrast medium in gastrointestinal segment (entry time) and when about 90% of the intraluminal contrast medium had left the organ (from initial dosing time 0, emptying time) were recorded. Contrast medium adhering to mucosa or cuticula was still recorded after this emptying time. These times were mainly determined from the lateral radiographs; however, available DV views were consulted for additional information.

*Baritop-100 suspension, Noristan Limited, Pretoria, South Africa

Results

Survey Radiographs

Findings were as described previously.[7]

Views and Adaptations for Contrast Studies

In the chicks, no exposure factor compensation was required. In adult ostriches, the following adaptations were necessary.

- D1: For the cranial coelomic cavity, the kVp settings were adapted to those of the cranioventral (V1) view used with 1/2 of its mAs.
- V2: No compensation was required.
- V3: Within the first 40 min post contrast medium administration, a small cassette could be used as only the ventriculus was filled. After 2 h the kVp had to be increased by 15% to compensate for the increased intestinal opacity attributable to the barium.

Contrast Radiographs

There was substantial variation in the visibility and identification of gastrointestinal components as well as entrance and emptying times. The most suitable views are indicated after each organ.

Esophagus (adapted D1). Barium sulfate was immediately visible. In particular, the caudal quarter had a striated linear pattern that continued into the craniodorsal third to half of the proventriculus. These striations persisted for up to 23 h.

Proventriculus (adapted D1, V2) (Figs. 1–3). The proventricular filling was immediate and complete in chicks and considered to be sufficient in adults (around 60%). Proventricular size was unaffected by its filling status. The proventriculus started as a dilatation of the esophagus at the level of the 5th vertebral rib and extended to the 9th vertebral rib before it continued as a sac-like caudal dilatation. In chicks, it had an almost bicompartmental appearance. Mobility and contractility could be appreciated on serial radiographs because of slight changes in position and folding of the dorsal pouch.

During emptying, the fluid line dropped slowly, leaving more room dorsally for gas. Emptying time ranged from 1–3 h. However, the wall was coated with contrast medium and remained vaguely visible for a long time (up to 23 h).

Ventriculus (adapted D1, V2) (Figs. 1–3). Filling started immediately. The position of the ventriculus was constant with 2/3 of the ventriculus being positioned on the sternum and one third caudally to it. Rotation around its long-axis occurred in some instances and was characterized by its asymmetric, typically well-developed biconvex shape.

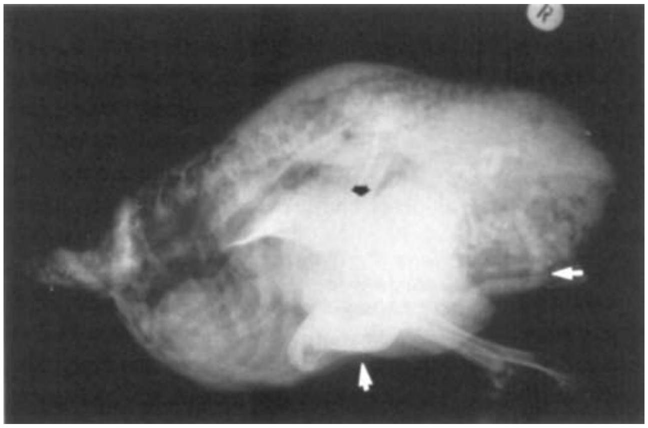

FIG. 1. Whole body left-to-right laterally recumbent radiograph of a 4-week-old ostrich chick (Table 1, No. 1) at 39 min. Note the almost bicompartmental (black arrow) and the cranial striated appearance of the dorsally located proventriculus. The ventrally located ventriculus (white arrow pointing up) is outlined revealing its biconvex shape. The u-shaped tubular structure in the caudal coelomic cavity represents the duodenum (white arrow pointing to the left), and the thinner tubular structures of irregular diameter represent other small intestine. Abdominal air sacs are compressed and hence not seen because of lateral recumbency.

Emptying time did not exceed 5 h and was long compared to adjacent gastrointestinal components. Contrast medium coating of luminal content (stones) and cuticula were visible up to 23 h.

Small intestine (V3). a) Duodenum (Figs. 1, 3A). The duodenum became visible after about 20 min as a double, flexed on itself, tubular structure cranioventrally on V3. The position of its duodenal flexure varied, and could be caudally or dorsally orientated. The duodenum had a constant diameter throughout, contrary to the rest of the small intestine, and was wider than the latter. It was empty by 1 h and was best seen during initial filling.

b) Remainder of small intestine (Figs. 1, 2A–D). The filling time was difficult to determine because the leading edge was indistinct (independent of concentration). An indistinct contrast medium appearance could be seen shortly after the initial duodenal filling which progressed later to a definite filling. Individual components of the small intestine could only be distinguished by their chronological appearance. The proximal small intestine (jejunum) tended to be located more dorsally in the cranial to mid-coelomic region. The distal small intestine (ileum) was more caudal and ventral in the mid-abdomen with variations occurring. Later contrast medium filling led to myriad overlapping small intestine loops hampering identification of individual structures. The diameter was highly variable, and a mild pearl-string appearance was seen occasionally, particularly in the distal small intestine.

Large intestine (V3). a) Caeca (Figs. 2C, 2D). One or both caeca were inconsistently opacified and mostly only for a short time. They could contain contrast medium as early as 1 h 40 min. They were visible before any similar distinct filling appeared in the proximal rectum. The tapering shape of the caeca became visible on V3, with its widest diameter close to its opening in the cranial midabdomen (dorsal third of the 9th vertebral rib). Linear filling defects ran transversely to its length at fairly regular intervals. The widest caecal diameter was approximately twice that of the proximal rectum, which width was fairly constant. The caecal spiral fold interval was up to 4.5 wider than those of the proximal rectal folds.

b) Proximal rectum (Figs. 2C, 3, 4). Initial clear filling of individual loops was observed in the dorsocranial aspect and could be seen first around 3 h. Later it extended to the rest of the caudal coelomic cavity, resulting in numerous overlapping large intestines, leaving only the very caudal pericloacal area unimpeded. Contents consisted of barium intermixed ingesta with medium-sized gas bubbles. The aboral part of the proximal rectum was still vaguely visible after 24 h.

c) Distal rectum (Figs. 2E, 2F). It had a pronounced pearl-string appearance and was markedly thinner than the proximal rectum and characterized by its barium-coated fecal pellets. Caudally (pericloacal region) it had a spiral–conical formation (area that was previously unimpeded by the proximal rectum). Contrast medium was visible to the end of the study. No linear filling defects were seen as opposed to the proximal rectum. A marked dilatation of the terminal part of the distal rectum was filled with multiple fecal balls next to each other and was outlined with gas. It was separated from the cloaca by the rectocoprodeal fold that was visible as a soft tissue opacity.

Cloaca (V3). A round soft tissue opacity structure of varying size was noticed in the cloacal region with the terminal part of the distal rectum entering on its dorsal aspect. Its size increased over time, and it had an obvious fluid line. It drastically decreased in size after urination. This structure, the coprodeum, never filled with contrast medium.

Concentration and Dosages

Dosages of 7 or 10 ml/kg gave adequate filling of the various gastrointestinal components in chicks and adults. Complete filling of the proventriculus occurred in chicks; whereas, in adults, the proventriculus filled to about 60%, which was considered sufficient. Chicks appeared to have a more rapid transit time, and 10 ml/kg of a 50% w/vol barium sulfate suspension gave the best results. In chick No. 3 (Table 1) 10 ml/kg of a 25% w/vol barium sulfate suspension resulted in too little opacification, and the procedure was aborted.

In adult ostriches, 10 ml/kg of a 25% w/vol barium sulfate suspension resulted in good opacification; whereas, a 50% w/vol barium sulfate suspension at the same volume resulted in too much superimposition of contrast medium in the caudal coelomic cavity. Reducing the volume to 7 ml/kg

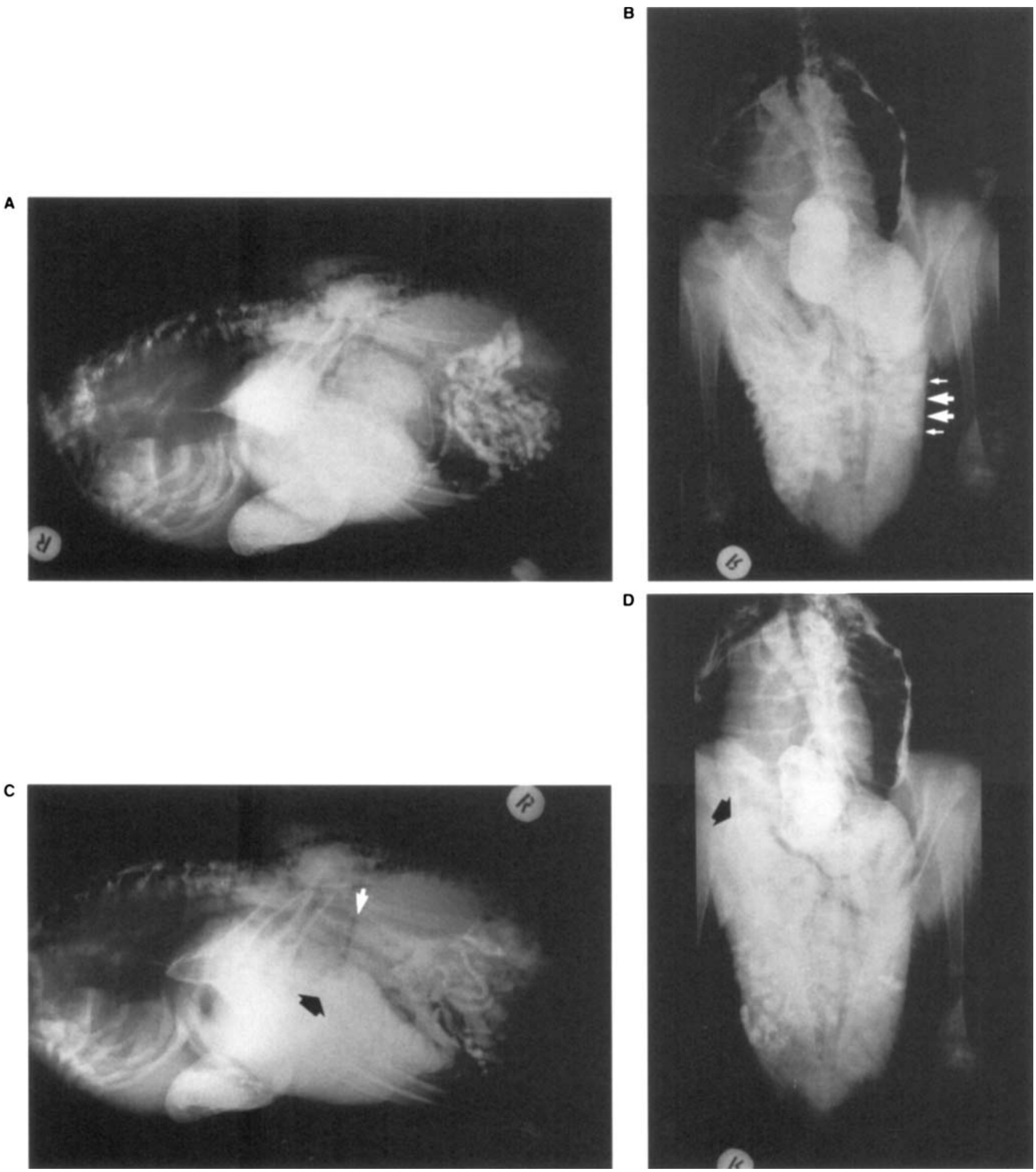

FIG. 2. Same chick as in Fig. 1. Opposite figures represent left-to-right lateral (right lat.) views and dorsoventral (DV) views made at approximately the same time and should be studied simultaneously. Only additional information is mentioned for the DV. (A) Right lateral at 1 h 7 min. The proventriculus and ventriculus still contain contrast medium. Myriad small intestine are visible in the caudal coelomic cavity; (B) DV at 51 min. Central cranially positioned ventriculus with proventriculus located caudally and to its left, the u-shaped duodenum (white large arrows) is visible as well as the ileum (white small arrows). Myriad small intestine are mainly located in the right caudal coelomic cavity; (C) Right lateral at 2 h 20 min. Some proventricular and ventricular contrast medium is still visible. Some small intestine are well outlined, but differentiation is no longer possible. Thicker, less well-defined tubular structures with radiolucent linear filling defects at regular intervals represent the proximal rectum (white arrow). The larger diameter diagonal coursing tubular structures represent the caeca (black arrow). These structures also have linear filling defects at regular intervals, but they are further apart than in the proximal rectum; (D) DV at 2 h 20 min. The ventriculus still has some luminal contrast medium; whereas, the proventricular wall is only coated with contrast medium. The caeca (black arrow) are visible in the central right coelomic region. Contrast persists in some small intestine. The proximal rectum is only faintly visible; (E) Right lateral at 23 h. Note the very vague outline of the striated proventricular wall (white arrow). Luminal ventricular contrast medium is gone, but its content is still coated. Note the spiral–conical accumulation of the distal rectum in the caudal coelomic cavity (pericloacal region); (F) DV at 23 h.

of a 50% w/vol barium sulfate suspension also resulted in good opacification. However, 7 ml/kg of a 25% w/vol barium sulfate suspension resulted in poor contrast. The transit time did not seem to be affected by different barium concentrations. A concentration of a 100% w/vol barium sulfate suspension (Table 1, No. 2) resulted in delayed transit time without improved opacification and was not investigated further. This high concentration also resulted in contrast medium sedimentation in the stomach tube and dosing bucket.

Discussion

Ostriches do not possess a crop, thus the stomach tube can be positioned distally into the esophagus. The proventriculus filled immediately and appeared to have a consistent volume independent of its filling status with only the barium–air interface height varying according to dosage. Contrast medium adhered to the proventricular mucosa and ventricular cuticula for up to 23 h, which was long after these organs had emptied.

The duodenum was consistently visible, but only for a short time, even though contrast medium was still present in the proventriculus and ventriculus. However, superimposing other structures as well as exposure factor differences may have hampered its evaluation. The duodenal flexure was very mobile.

The remaining small intestine had a very coiled appearance. Filling time was difficult to assess because the exact time of contrast medium entrance into this region was impossible to define. Individual segments of the small intestine were not distinguishable but could be identified as jejunum or ileum according to contrast medium transit.

One or both caeca were inconsistently opacified with contrast medium and then only for a short time, thus these segments may not always be seen routinely. The linear filling defects seen perpendicularly to the tubular orientation represented the spiral folds of the caeca and can be distinguished from the plicae of the proximal rectum, which are located closer to each other. In addition, the wider diameter of the caeca versus proximal rectum (up to 2:1) can be used to distinguish these two organs. It is, however, important to note that the caecal diameter tapers markedly from proximal to distal and that the spiral folds are only present in the proximal 2/3. The best large intestinal images were obtained at 12 h.

Caecal contrast medium was seen prior to prominent filling of the proximal rectum. This is contrary to the theory of retrograde caecal filling by means of antiperistalsis from the proximal rectum in avian species.[9] However, further investigation is needed to corroborate this finding.

The anatomic description[10] that the proximal rectum is located more to the left and the distal rectum more to the right could not be validated in this study. Their locations seemed to be more in a craniocaudal direction with the distal rectum accumulating spirally in the pericloacal region, while the proximal rectum filled the remaining cranial space.

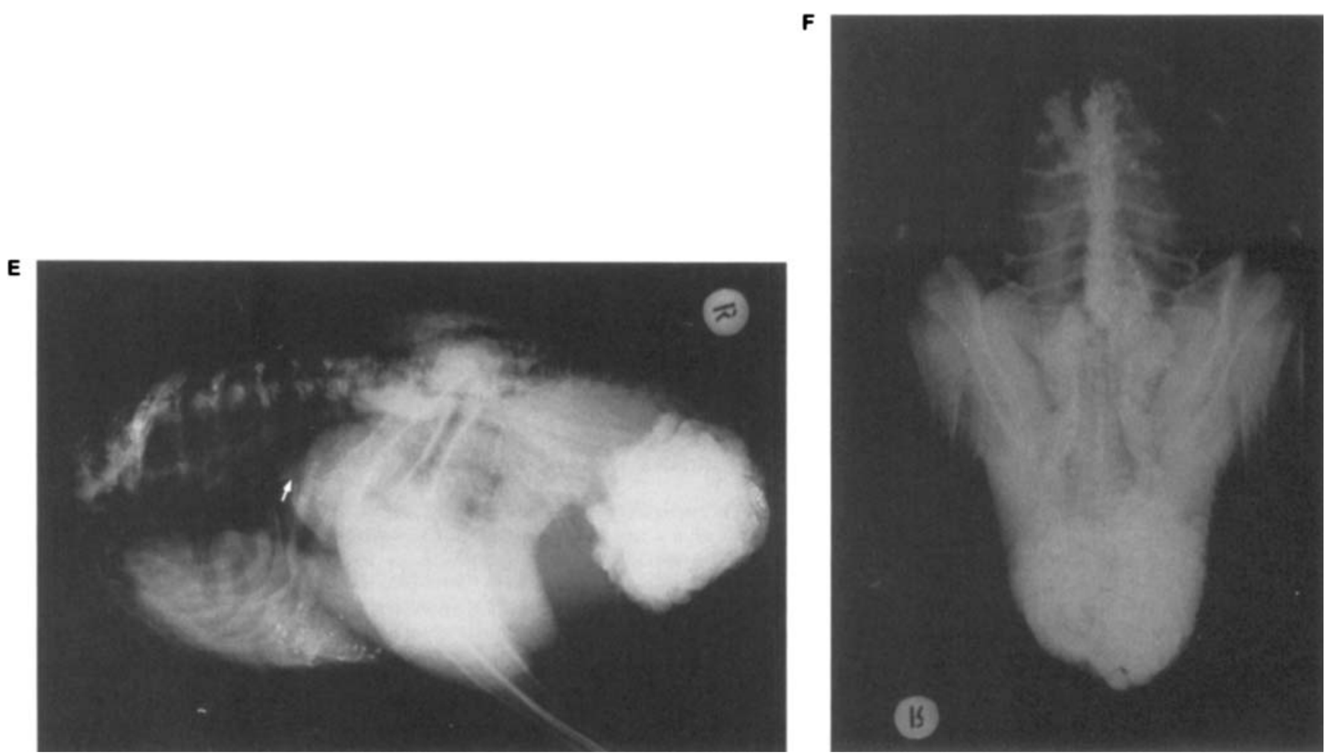

FIG. 2. Continued.

A B

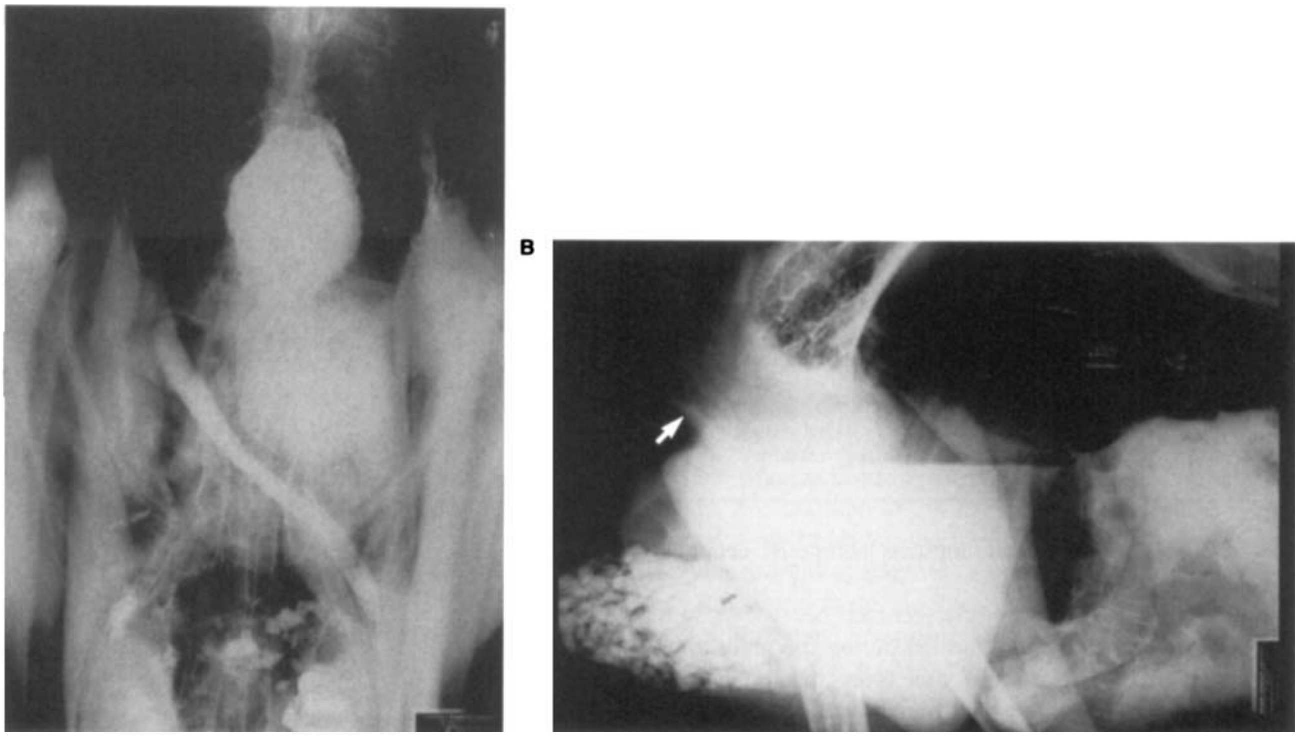

FIG. 3. Radiographs of a 20-week-old ostrich (Table 1, No 5). (A) Mid-dorsoventral (DV2) view in sternal recumbency at 23 min. The cranially located ventriculus is completely filled and is positioned further cranially than in chicks. The proventriculus is only filled caudally. The diagonally running tubular structure represents one limb of the duodenum. Early poorly defined filling of the remainder of the small intestine; (B) Mid-ventral (V2) view at 8 h 3 min. The proventricular wall is only faintly visible (white arrow). "Fluid line" is created by the summation of pelvic limb musculature, air sacs, and gas and content in the proventriculus. No ventricular contrast medium, but a lot of content, is still coated by contrast medium. The ventrocaudal abdomen is filled with superimposing loops of the proximal rectum.

No contrast medium ever filled the ventral pouch of the coprodeum (round soft tissue opacity in the cloacal region) at any stage, even though traditionally it is believed to be part of the fecal storage area in birds.[11] This would support the theory that, in ostriches, the ventral pouch of the coprodeum has taken on an urine storage function[7,12,13] and is independent of the gastrointestinal system.

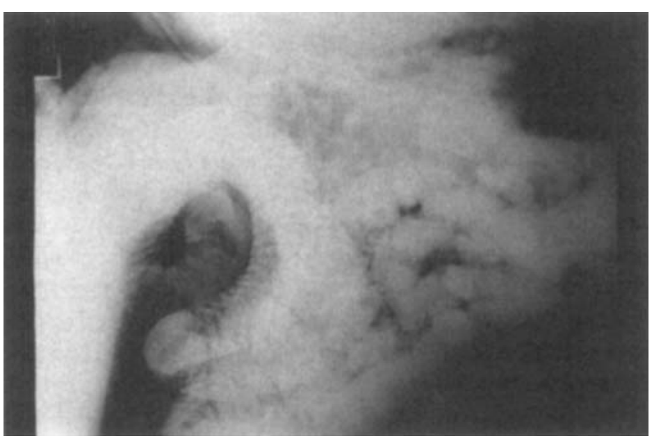

FIG. 4. Left-to-right caudoventral (V3) view of a 3-year-old ostrich at 14 h (Table 1, No. 7). The caudal edge of the thigh muscles is seen as solid soft tissue opacity cranioventrally. The tubular loops represent proximal rectum; whereas, the loops of the distal rectum have a more pearl-string appearance and reveal early fecal ball formation.

The following organs could routinely be identified during the contrast study: esophagus, proventriculus, ventriculus, duodenum, jejunum, proximal rectum, and distal rectum. The degree of visibility of these organs did vary to some extent. Inconsistently identified/visible were the ileum and one or both caeca. The secondary duodenal loop was not visible on any study. The esophagus, proventriculus, ventriculus, proximal and distal rectum, and the cloaca locations were consistent. The duodenal flexure, the remainder of the small intestine, and the aboral tips of the caeca were found in variable locations within and among birds.

The evaluation and identification of individual structures can be difficult on lateral views alone, and DV views should also be attempted. If this is impossible, right-to-left and left-to-right lateral views may provide additional information.

Entry and emptying times were not easy to define for multiple reasons: 1) high exposure factors might have obscured small amounts of contrast medium; 2) adherence of contrast medium to mucosa, cuticula, and coating of luminal content might have mimicked filling; and 3) superimposi-

TABLE 2. Recommended time frequency for radiographs during gastrointestinal contrast studies in ostriches. The views[8] and adaptations thereof as well as the envisaged organs are indicated. Survey radiographs[8] of D1, V2 and V3 have to be made prior to contrast medium administration. The recommended dosage for ostrich chicks is 10 ml/kg of a 50% w/vol barium sulfate suspension and for adults 10 ml/kg of a 25% w/vol suspension.

Time	Views	Adaptation	Envisaged Organs
Immediately	D1	V1 Exposures with ½ mAs	Esophagus, proventriculus
20 min	V2	No	Ventriculus
20 min	V3	Small cassette possible	Duodenum
40 min	V3	No	Small intestine (jejunum)
1 h	V3	No	Small intestine
2 h	V3	Increase kVp by 15%	Caeca
3–4 h	V3	Keep kVp increased	Proximal rectum
8–14 h	V3	Keep kVp increased	Large intestine
24 h	V3	Keep kVp increased	Distal rectum

tion of compact convoluted intestine hampered accurate evaluation.

Transit time was not precisely recorded because barium sulfate-stained feces were defecated during the night after 14 h but before 22 h. This transit time is less than previously reported.[5,6] Because of the long transit time, the intestinal tract cannot and should not be emptied completely (in order to maintain essential intestinal flora). Fasting for 16 h reduced intestinal content significantly, but this may not be feasible in clinically compromised birds.

Ten ml/kg of a 50% w/vol barium sulfate suspension for chicks and 10 ml/kg of a 25% w/vol barium sulfate suspension in adults were found to be optimal concentrations and volumes (Table 2). Higher concentrations (>50% w/vol) are not recommended because of barium sedimentation, danger of constipation, increased superimposition, and decreased transit time. Dosages will also depend on the study objectives. Should, for example, the large intestine need to be evaluated, the starting time should be chosen so that the optimal visualization of the organ falls within working hours.

Conclusion

This study was undertaken to describe the appearance of the normal gastrointestinal tract in the ostrich with contrast radiography. The authors believe that it is a useful procedure to answer anatomic and physiologic questions as well as for diagnostic purposes. However, for the latter, the veterinarian must be aware that this procedure is time consuming, costly, and that contrast medium administration may be stressful.

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