Article — Artikel

Radiographic anatomy of the thoraco-abdominal cavity of the ostrich (*Struthio camelus*)

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ABSTRACT

This study provides a reference for the radiographic anatomy of the thoraco-abdominal cavity of female ostriches as a representative of ratites. One ostrich cadaver, 2 adult and 2 growing ostriches were used. Right lateral radiographs produced by a 6-frame technique and 2 dorsoventral radiographs produced by an adapted 3-frame technique were selected and schematic illustrations of these were labelled to illustrate normal radiographic anatomy. Differences from other avian species and unique features of the ostrich are briefly discussed.

Key words: anatomy, ostriches, radiographic anatomy, radiography, ratites, *Struthio camelus.*

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INTRODUCTION

Ostriches (*Struthio camelus*), together with the kiwi, emu, rhea and cassowary, are classified as ratites, and are the most economically important representatives of this group. The value of radiology in evaluating avian patients is well recognised, but its application to ratites has been limited by a lack of normal reference material and the distinctive anatomy of ratites.

In a previous study[9] the authors were able to develop a standardised radiographic technique for ostriches that provides consistently good radiographs of diagnostic potential. The purpose of the current study is to expand this original work and to provide an atlas of normal radiographic anatomy of the ostrich thoraco-abdominal cavity. Accurate interpretation of these radiographs requires a thorough knowledge of ratite anatomy.

Although several articles have been published on diagnostic imaging of ratites[4,8,10,12], to the best of the authors' knowledge no detailed radiographic anatomic description of the thoraco-abdominal cavity of the ostrich, or ratites in general, has been published.

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MATERIALS AND METHODS

A high output rotating anode fixed X-ray apparatus (Polydoros 100, Siemens A.G., Erlangen, Germany), medium speed rare earth screens (Trimax T6, 3M, Milan, Italy) with compatible films and a focused 12:1 grid were used. The speed of this system was 300. The source-to-image distance (SID) was 115 cm.

Radiographic examination was performed as described previously[9], using a 6-frame technique for making left-to-right laterals in the standing ostrich and a 3-frame technique for the dorsoventral (DV) view in sternal recumbency. The 6-frame technique consists of a set of 3 dorsal and 3 ventral lateral radiographs, providing the following views: craniodorsal (D1); mid-dorsal (D2); caudodorsal (D3); cranioventral (V1); mid-ventral (V2); and caudoventral (V3). The 3-frame technique follows a craniocaudal orientation providing the following views: cranial dorsoventral (DV1); mid-dorsoventral (DV2); and caudal dorsoventral (DV3). Adaptations to the technique were made for younger birds where necessary.

One ostrich cadaver, 2 clinically normal ostrich chicks radiographed at 3-month intervals from the age of 3 weeks till 12 months as well as 2 clinically normal young adult female ostriches (2.5–3 years, before the 1st breeding season) were examined. This project was approved by the Ethics Committee of the Faculty of Veterinary Science, University of Pretoria.

RESULTS AND DISCUSSION

A set of left-to-right lateral (6-frame technique) radiographs of a 2.5-year-old female ostrich (Figs 1A–4A, 5, 6A) and 2 dorsoventral radiographs (adapted 3-frame technique) of a 16-week-old female ostrich (Figs 7A, 8A) were selected. Corresponding schematic illustrations of these are provided except for the mid-ventral (V2) view, and selected structures were identified and labelled (Figs 1B–4B, 6B–8B). Radiographs were left unlabelled so as not to obscure details.

Not all radiographs demonstrate complete schematic detail. This detail was derived from several radiographs of the same view and is included to provide a complete reference. Furthermore, reproduction resulted in some loss of detail, hampering identification of subtle structures on some radiographs. Bony structures are labelled throughout in upper case, thoraco-abdominal visceral structures in lower case, except for vascular structures, which are labelled with numerals.

Ostriches have multiple anatomic features that differ from domestic and pet birds, and should be considered when interpreting radiographs. The following brief discussion of the ostrich radiographic anatomy also emphasises differences from other avian species. The most suitable lateral and DV views are indicated after the organ system in brackets.

Musculoskeletal system

Ratites derive their name from the Latin word *ratis*, meaning raft, which describes their unique sternum with its concave shape. This anatomical structure hampers visualisation of the ventral aspect of the cranially situated organs (heart and liver) (Fig. 4). In contrast to domestic avian species, the ostrich does not possess a notatorium (fused thoracic vertebrae), pygostyle (fused caudal vertebrae) or clavicles, and the pubic bones fuse ventrally. Instead of a pneumatised humerus, as seen in the chicken, the ostrich possesses a pneumatised femur making the cortices clearly visible (Fig. 2). The wings are greatly reduced, but they should nevertheless be tied up dorsally for lateral

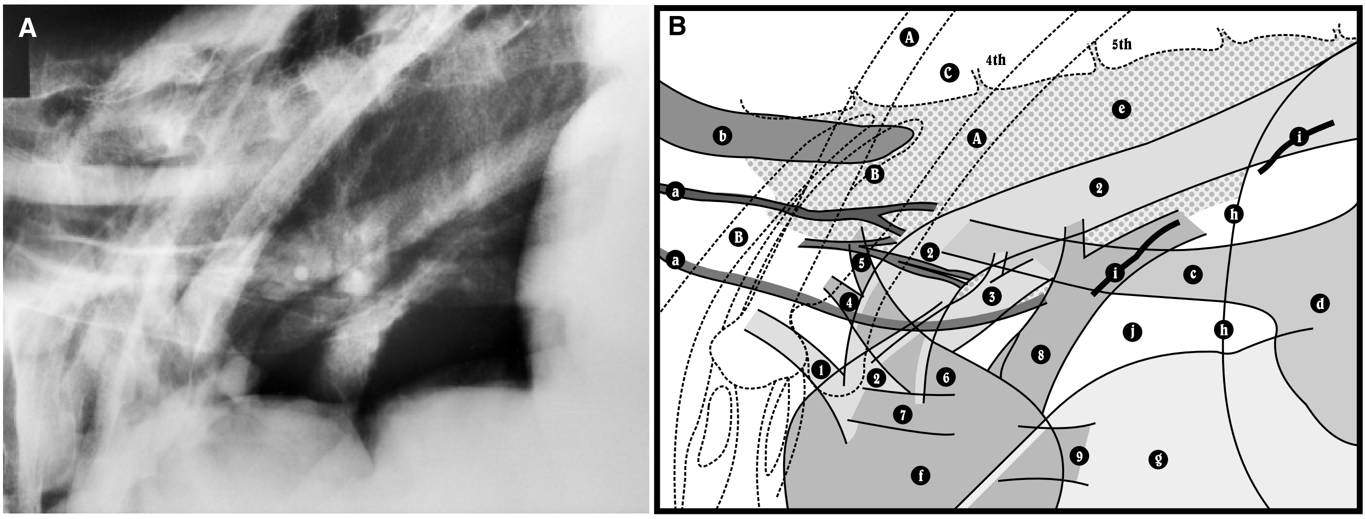

Fig. 1: **Left-to-right lateral radiograph taken in a standing 2.5-year-old female ostrich using a 6-frame technique.** (A) **D1 view;** (B) **schematic illustration of A.** A = humerus, B = scapula, C = thoracic vertebra, a = trachea splitting up into extrapulmonary main bronchi, b = longus colli muscle, c = esophagus, d = proventriculus, e = lung (dotted area), f = heart, g = liver, h = cranial edge of thigh muscles, i = horizontal septum, j = caudal thoracic air sacs, 1 = brachiocephalic trunk, 2 = aorta, 3 = pulmonary arteries, 4 = jugular vein, 5 = subclavian vein, 6 = right cranial vena cava, 7 = left cranial vena cava, 8 = pulmonary veins, 9 = caudal vena cava.

radiographs in order to minimise superimposition (Fig. 1). The large upper thigh muscles, adapted to a cursorial lifestyle, hamper visualisation of the middle body area in lateral views (Figs 2, 5), but especially mid-ventrally (V2). Although V2 can be diagnostic for foreign bodies and impactions in the ventriculus or proventriculus, radiographic detail is limited. Visualisation of this area can be improved by positioning the legs slightly apart. Because the synsacrum does not form a renal fossa, the kidneys are located ventral to the bone, improving their visibility (Figs 2, 3).

In contrast to previous reports[1,3], a number of anatomical variations were found in the ostrich. The number of the vertebral ribs varies from 8 to 9. So does the number of ribs attaching to the sternum, most commonly vertebral ribs 3 to 7. The scapula ends caudally between the 3rd and 4th vertebral ribs. Uncinate processes, small bony processes located caudally on the ventral third of the vertebral ribs, are present on the 3rd–5th or 4th–6th vertebral ribs. The 8th vertebral rib may have a cartilaginous attachment to the sternum. These variations are important, because these landmarks serve as radiographic centering points[9].

Cardiovascular system

Heart (Figs 4, 7)

A cranial DV (DV1) with abdominal settings must be used (Fig. 7). The normal hour-glass appearance of the heart/liver silhouette noted in VD views of pet birds[5] is not seen in ostriches. The heart assumes a much more upright position, with little sternal contact (Fig. 4).

Blood vessels (Figs 1, 7)

Owing to the ostrich's size, identification of individual blood vessels is easier than in smaller avian species. Vessels of the renal-portal system are clearly visible in cross-section in lateral views (Fig. 2). Additionally, initial portions of the coeliac and cranial mesenteric arteries can sometimes be seen leaving the aorta at the level of the 7th and 8th ribs as opaque, soft tissue, tubular structures running caudoventrally.

Lymphatic system (Figs 2, 7)

The spleen can be visualised in lateral views (Fig. 2) but the superimposed hind limb musculature may hamper its visibil-

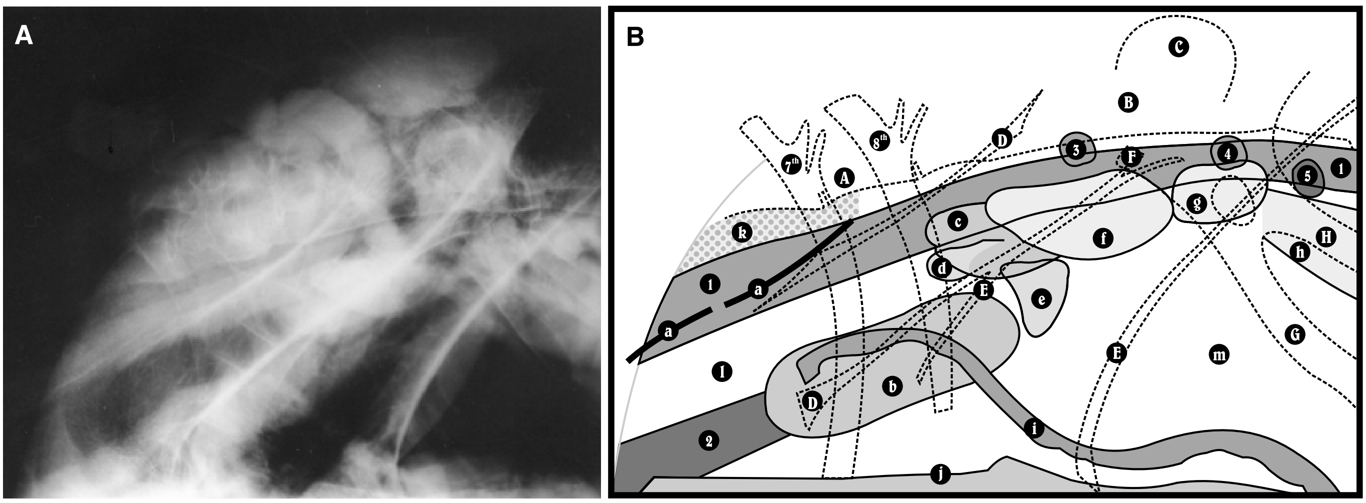

Fig. 2: **Same as Fig. 1.** (A) **D2 view;** (B) **schematic illustration of A.** A = thoracic vertebra, B = synsacrum, C = acetabulum, D = right femur, E = left femur, F = pectineal process, G = pubis, H = ischium, a = horizontal septum, b = spleen, c = ovary, d = left adrenal gland, e = right adrenal gland, f = cranial lobe of kidney, g = middle lobe of kidney, h = caudal lobe of kidney, i = dorsal wall of proventriculus, j = ingesta–air interface, k = lung, l = caudal thoracic air sacs, m = abdominal air sacs, 1 = descending aorta, 2 = caudal vena cava, 3 = external iliac artery, 4 = ischiadic artery, 5 = ischiadic vein.

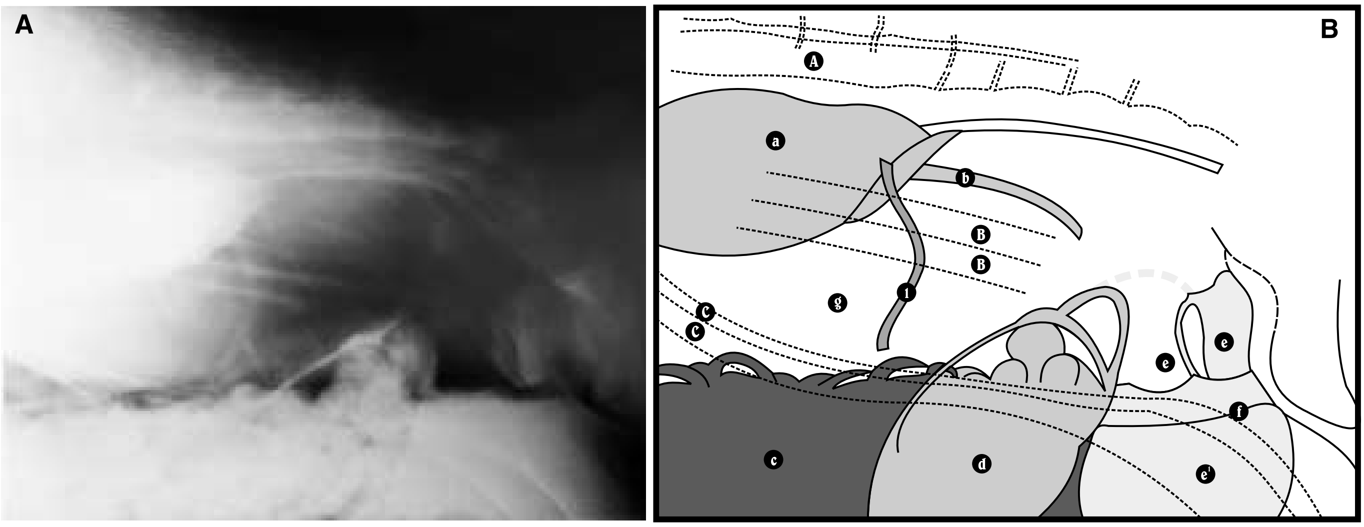

Fig. 3: **Same as Fig. 1.** (A) **D3 view;** (B) **schematic illustration of A.** A = synsacrum, B = ischii, C = pubes, a = caudal lobe of kidney, b = ureter, c = ingesta-filled intestines, d = distal dilatation of rectum, e = cloaca, e' = fluid-filled ventral sac of coprodeum, f = fluid line in coprodeum, g = perirenal diverticula, 1 = caudal mesenteric artery.

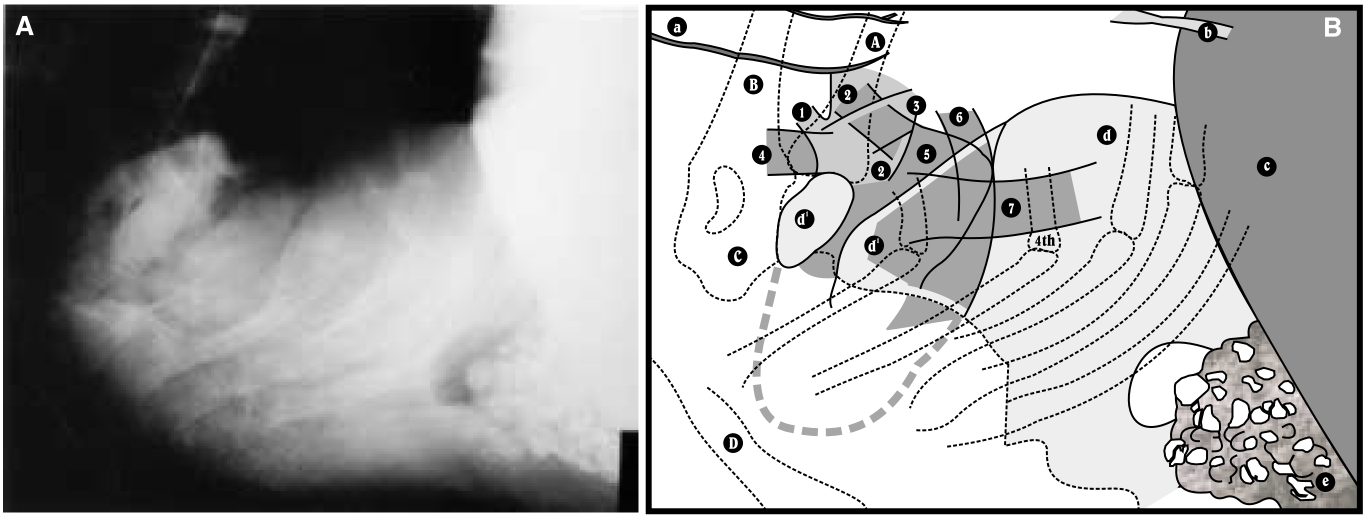

Fig. 4: **Same as Fig. 1.** (A) **V1 view;** (B) **schematic illustration of A.** A = humerus, B = scapula, C = coracoid, D = sternum, a = trachea, b = ventral wall of esophagus, c = cranial aspect of thigh muscles, d = liver, d' = liver lobes superimposing over cardiac shadow, e = lumen of ventriculus with stones, 1 = brachiocephalic trunk, 2 = aorta, 3 = pulmonary artery, 4 = left cranial vena cava, 5 = right cranial vena cava, 6 = pulmonary vein, 7 = caudal vena cava.

ity. On DV views it is located on the right side (Fig. 7).

Respiratory system

Lungs (Figs 1, 7)

To interpret the lungs in dorsoventral view, DV1 with thoracic settings should be used (not illustrated here) and the cassette placed transversely to the body axis[9]. The horizontal septum, the ventral border of the lung, is visible in normal ostriches (Fig. 1). This is in contrast to pet birds where it becomes visible only in pathological conditions such as air sacculitis.

The honeycomb pattern of the lungs extends further ventrally on the sides, giving the impression that the lungs extend ventral to the centrally visualised horizontal septum (Figs 1, 2) in lateral views.

Bronchi are clearly visible to the level of parabronchi (tertiary bronchi) in the central area. One principal bronchus is consistently imaged dorsal to the other. In DV views the continuation of the main bronchi (mesobronchus) into the abdominal air sacs can occasionally be distinguished (Fig. 7).

Air sacs (Figs 1–3, 7)

The borders of the air sacs are not visible in healthy birds. They can be observed in clinical cases of air sacculitis when they become thickened (pers. obs.). Pathological exudates within the air sacs should be visible as soft tissue opacities. The cranial and caudal thoracic air sacs are more prone to air sacculitis (pers. obs.) and should be examined carefully. This is curious in light of published avian respiration theories[7], which postulate that the

Fig. 5: **Same as Fig. 1. View V2. The large leg muscles hamper visualisation of the middle body area. Even though radiographic detail is poor, this view has diagnostic potential for foreign bodies and impactions in the ventriculus or proventriculus. The ventriculus can be seen due to its physiological content (stones) cranioventrally to the soft tissue opacity of the leg muscles.**

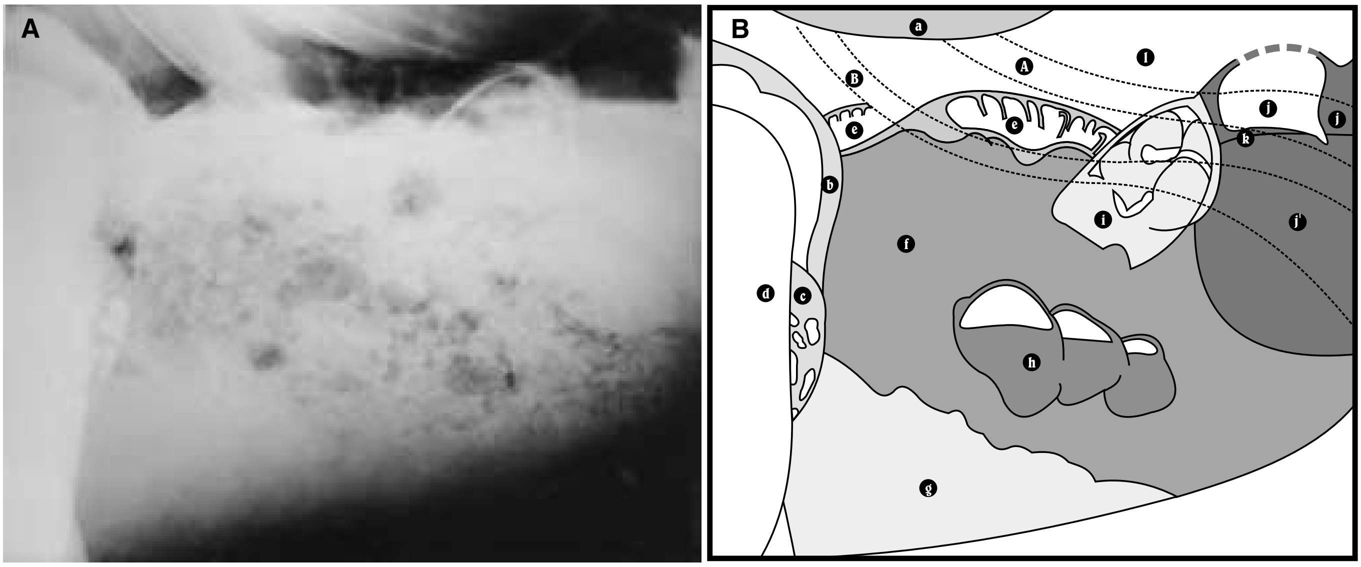

Fig. 6: **Same as Fig. 1.** (A) **V3 view;** (B) **schematic illustration of A.** A = ischium, B = pubis, a = caudal lobe of kidney, b = wall of proventriculus, c = ingesta and stones (unusual) in proventriculus, d = caudal edge of thigh muscles, e = proximal rectum, f = ingesta- and gas-filled intestines, g = fluid/ingesta-filled intestines, h = caecum, i = distal pouch of rectum, j = cloaca, j' = fluid-filled ventral sac of coprodeum, k = fluid line in coprodeum. l = perirenal diverticula.

abdominal air sacs are ventilated first.

In contrast to domestic fowl[6], the left abdominal air sac is longer than the right[3], but neither extends as far caudally as in pet birds. Thus, in DV views, the caudal cavity does not show radiolucent areas peripherally. The large perirenal diverticula of the abdominal air sacs create a wide radiolucent area dorsal to the horizontal intestinal interface, providing good contrast for the caudal lobes of the kidneys (Fig. 3) in the standing lateral views. The gastric diverticulum of the clavicular air sac can sometimes be seen as a thin radiolucent margin caudal to the proventriculus.

Digestive system

Foregut (Figs 1, 2, 4, 5, 7)

Ostriches do not posses a crop. The oesophagus, as in other avian species, is readily visible (Fig. 1). The proventriculus extends further caudally than the ventriculus. Its dorsal wall is visible because of an accumulation of gas in the proventriculus and the surrounding air sacs (Fig. 2). An ingesta-air interface is usually visible in the lumen of the proventriculus (Fig. 2). The ventriculus itself is not visible because of its close contact with other soft tissue opacities such as the liver. Its lumen, however, is clearly differentiated

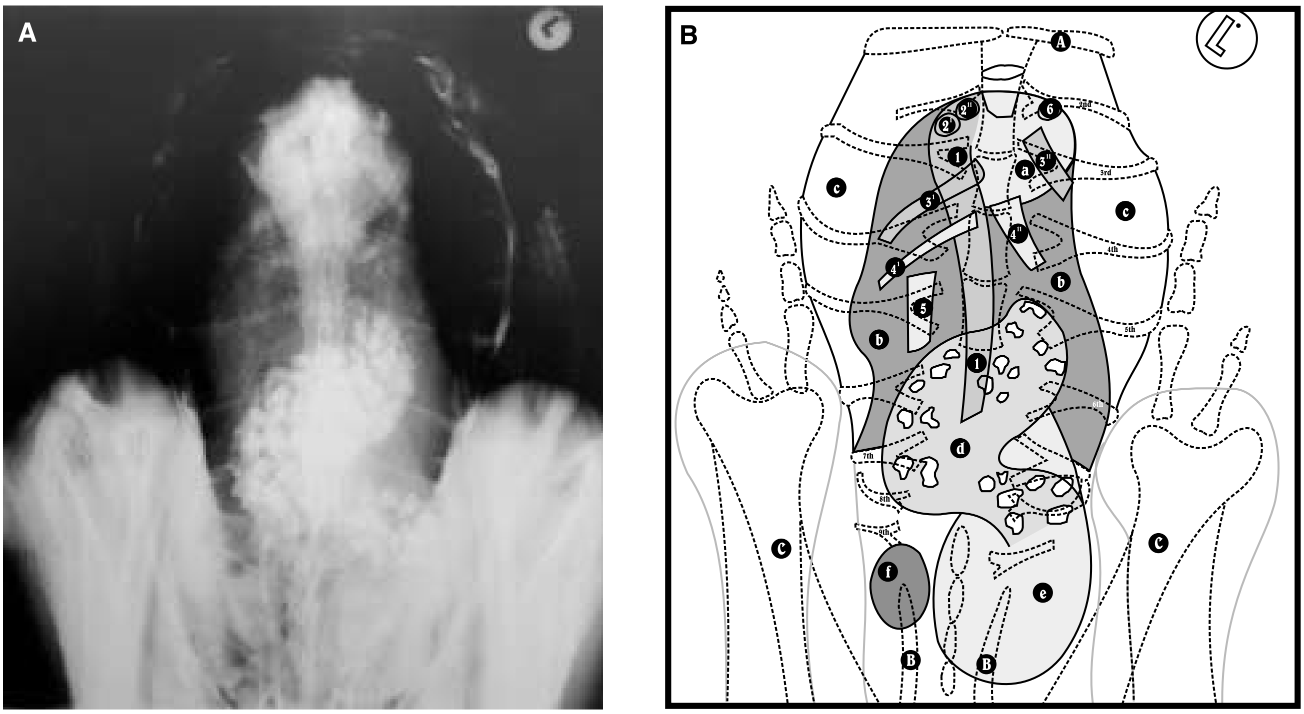

Fig. 7: **Dorsoventral** (DV) **adapted series resulting in a 2-frame technique of a 16-week-old female ostrich in sternal recumbency.** (A) **cranial DV;** (B) **schematic illustration of A.** A = coracoid, B = ilium, C = femur, a = heart, b = liver, c = cranial and caudal thoracic as well as clavicular air sacs, d = lumen of ventriculus with stones, e = proventriculus, f = spleen, 1 = descending aorta, 2' = right brachiocephalic trunk, 2'' = left brachiocephalic trunk, 3' = right pulmonary artery, 3'' = left pulmonary artery, 4' = right pulmonary vein, 4'' = left pulmonary vein, 5 = caudal vena cava, 6 = left cranial vena cava.

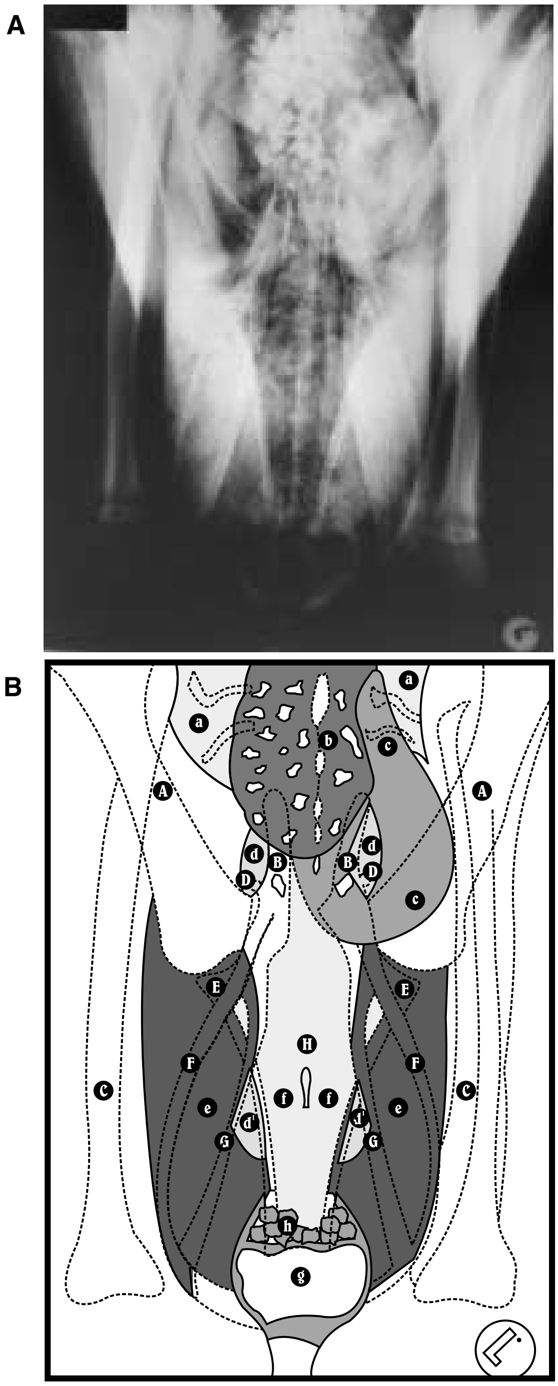

Fig. 8: **Same as Fig. 7.** (A) **caudal DV;** (B) **schematic illustration of A.** A = femur, B = ilium, C = superimposition of tibiotarsus and tarsometatarsus, D = pectineal process, E = antitrochanter, F = pubis, G = ischium, H = synsacrum, a = liver, b = ventriculus filled with stones, c = proventriculus, d = cranial lobe of kidney, e = ingesta-filled intestines, f = more radiolucent appearance of ingesta because of superimposition of perirenal diverticula, g = cloaca, h = distal pouch of rectum.

because of its stone-filled contents (Figs 4, 5). In pet birds the ventriculus is situated further caudally, whereas in the ostrich the ventriculus begins at the caudal aspect of the sternum.

Intestines (Figs 6, 8)

The ostrich intestines fill most of the caudoventral cavity, leaving no lateral radiolucencies in DV views as seen in other species (Fig. 8). Despite the first impression of a fairly homogeneous soft tissue opacity of the ventral ⅔ of the caudal abdominal cavity (Fig. 6), 3 areas can be differentiated: a cranioventral triangular area of homogeneous soft tissue opacity, representing a fluid/ingesta filled area; a caudodorsal triangular area; and a mottled diagonal stripe between the 2, representing an ingesta-gas mixture.

Against a background of detailed anatomical knowledge, additional structures that can be identified in the caudodorsal triangular area include: 1) at least 1 of the 2 caeca in the mid-abdominal area, which is characterised by its widely plicated appearance due to an internal spiral fold[2], giving it a similar appearance to the caecum of the horse; 2) the proximal rectum, because of the visible plicae at short intervals[3], can best be detected over the whole length of the dorsal horizontal ingesta–air border; 3) the distal rectum with its bandlike appearance of faecal balls and its small diameter of loops in the caudal and especially caudoventral abdomen; 4) the distal pouch of the rectum with its dramatic dilation to a sac-like structure that is filled with faecal balls and must not be confused with the cloaca; 5) the cloaca itself is separated from the latter by the rectocoprodeal fold[11], which is sometimes visible on radiographs; and 6) a round soft tissue opacity of varying diameter (decreased after urination) with a horizontal fluid line dorsally is located directly caudal to the distal end of the rectum. This has been described as the ventral sac of the coprodeum serving as urine storage compartment[11], which agrees with our own observations.

Intestinal gas is normal in ostriches and must not be confused with pathology as occurs in pet birds with enteritis or intestinal parasitism[5].

Glandular system (Figs 2, 4, 7)

The liver is situated further cranially than in pet birds and extends cranial to the heart, lying mainly on the sternum (Fig. 4). This, together with the upright heart, results in the total loss of the hour-glass shape of the cardiac-liver silhouette in DV views (Fig. 7).

The left cigar-shaped and right triangular adrenal glands can be seen cranial to the cranial lobes of the kidneys (Fig. 2).

Urogenital system (Figs 2, 3, 7, 8)

The left ovary can be visualised as a soft tissue opacity cranioventral to the cranial lobe of the kidney (Fig. 2). Cyclical variation of the gonads may have a marked effect on their appearance.

The caudal kidney lobes do not contact the gastrointestinal tract and therefore are clearly visible (Fig. 3).

In DV views the kidneys are poorly seen due to multiple superimposed structures (Figs 7, 8). The ureter is sometimes visible in lateral views as a tubular soft tissue opacity leaving the caudocentral aspect of the caudal kidney lobe and coursing caudoventrally (Fig. 3). A urinary bladder is missing, but the ventral sac of the coprodeum appears to have taken over this function (Fig. 6).

CONCLUSION

This article provides an atlas of normal radiographic anatomy of the thoraco-abdominal cavity of the ostrich, which should facilitate radiographic interpretation of pathological processes. The study provides additional anatomic information visualised in the ostrich that cannot be obtained from cadaver dissections. Adapting this study to other ratites should be possible, but one should be aware that a number of anatomical variations exist.

Additional diagnostic imaging techniques such as contrast studies of the gastrointestinal tract and urogenital system and ultrasound are currently being developed by the authors in order to provide a better understanding of the thoraco-abdominal cavity of the ostrich.

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Book review — Boekresensie

International aquatic animal health code

2001. Office International des Épizooties, Paris, 164 pp., soft cover. Price €40. ISBN 92 9044 538 6

It is well known that aquaculture is a rapidly expanding industry, but it is not always recognised that aquaculture is also a rapidly diversifying industry. Whereas traditional agriculture relies primarily on a limited number of domesticated species, none of the species used for aquaculture are fully domesticated and most are entirely undomesticated. In addition, new species are continuously being found suitable for culture in intensive production systems. The list of significant diseases of aquatic animals is growing as rapidly as the aquaculture industry itself. Internationally, the effects of translocation of species and the implications of intensive animal production in shared aquatic bodies are increasingly recognised. The need for guidance in managing the risks posed by international trade in aquatic animals and aquatic animal products is addressed by the Fish Diseases Commission of the Office International des Epizooties. In the foreword to the 2001 edition of the International Aquatic Animal Health Code, it is stated that both the Code and its companion work, the Diagnostic Manual for Aquatic Animal Diseases, will be reviewed annually, with a new edition of the Code printed every year.

The International Aquatic Animal Health Code provides guidance on certification of the health status of aquatic animals for international trade, as well on import risk analysis and procedures to limit risk during import and export. A section on contingency planning has been added. Specifics on control measures for notifiable and significant diseases are listed in separate chapters. Information on hygiene includes useful chapters on disinfection of fish eggs and aquaculture facilities. Model international health certificates for different types of aquaculture products are again included, with the addition of a certificate for dead crustaceans. Any regulatory authority involved in aquatic animal health will find in the contents of the Code a complete framework for developing control measures to limit the spread of disease. A wealth of relevant detail is present, for example the table on disinfectants for fish farms. It lists all the commonly used disinfectant processes, both physical and chemical, and gives the indications for use as well as the dosage or method of use. The Code is primarily aimed at regulatory authorities and is unlikely to be of interest to the general practitioner or aquaculturist. However, it is required reading for anyone involved in certification or any other aspect of disease control in aquaculture at a national or international level.

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