CHAPTER 9

Ratites or Struthioniformes: Struthiones, Rheae, Cassuarii, Apteryges (Ostriches, Rheas, Emus, Cassowaries, and Kiwis), and Tinamiformes (Tinamous)

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RATITES

General Biology

Ratite is not a strict taxonomic term; it is used to refer to flightless birds that do not have a keel but have, rather, a flat "raft-like" breast.[2,19] In general, ratites are classified in one order, Struthioniformes, with four suborders with distinct geographic distributions: (1) Struthiones are endemic to the African continent (apart from introduced populations in Australia), (2) Rheae in South America, (3) Casuarii in Australia and New Guinea, and (4) Apteryges in New Zealand.[19]

Struthiones include one family, Struthionidae, and one species with currently four recognized subspecies: (1) the North African ostrich (*Struthio camelus camelus*), (2) the Somali ostrich (*S. c. molybdophanes*), (3) the Massai ostrich (*S. c. massaicus*), and (4) the South African ostrich (*S. c. australis*).[19] Many farm populations (*S. c. domesticus*) are hybrids of various subspecies. Although ostrich farming became well established on the African, American, European, and Australian continents in the second half of the 20th century, wild ostriches have become exceedingly rare in some parts of their range. South Africa and East Africa still hold strong populations, but most of the *S. c. camelus* subspecies populations in West and North Africa are considered endangered.[14,19] The Rheidae, the only family to the suborder Rheae, are endemic to the Neotropical Region and include two species: (1) the Common or Greater Rhea (*Rhea americana*) and (2) the Darwin's or Lesser Rhea (*Pterocnemia pennata*). Although neither species is reckoned to be in immediate danger, both have been listed as near-threatened, and their numbers are declining in most parts.[19] The close genetic relationship between the families Dromaiidae (emus) and Casuariidae (cassowaries) is recognized by the common suborder Casuarii. Emus consist of one single species (*Dromaius novaehollandiae*) and occur in stable populations on mainland Australia, and the cassowaries constitute three clearly distinguishable species (Southern cassowary, *Casuarius casuarius*; Dwarf cassowary, *C. bennetti*; Northern cassowary, *C. unappendiculatus*), with a high number of subspecies.[19] All three species occur in altitudinally separate habitats in New Guinea, and the Southern cassowary also occurs in the northern parts of Australia. Because of defragmentation and reduction of their rain forest habitat, cassowaries are considered endangered.[19,41] The fifth ratite family, the kiwis (Apterygidae), is endemic to New Zealand and consists of three species (Brown Kiwi, *Apteryx australis*; Little Spotted Kiwi, *A. owenii*; Great Spotted Kiwi, *A. haastii*). Habitat destruction, inadvertent poisoning and trapping for pest control, and introduced predator species have greatly reduced their numbers and rendered some populations endangered, but because of their reclusive way of living, their status is poorly known.[29]

Whereas emus occur in a wide variety of habitats, ostriches prefer open semi-arid areas with short grass and are well adapted to hot and dry environments.[14,18,19] Rheas are characteristic to the semi-arid tall grass steppe and other savannah-type habitats of South America, but they like the vicinity of water or wetlands for breeding.[19] Cassowaries and kiwis are most typically found in rain forest habitats,[19,41] but because of destruction of habitat, kiwis are also to be found in other habitats with relative high humidity, adequate soil texture, and density of vegetation to dig their burrows. All ratites may swim.[19]

Ostriches and rheas are gregarious, diurnal birds, with males being territorial and entertaining polygamous social structures during breeding season.[14,18,19] Emus are usually found alone or in pairs except when they form large groups on the move or in places where water and food are abundant. Cassowaries are shy, solitary, and territorial all year round, with a mostly crepuscular activity pattern. Kiwis are almost entirely nocturnal, take refuge in earth burrows during the day, mate for life, and show strong attachment to their territory.[19]

Unique Anatomy

Except for the kiwi, the ratites are the largest birds in the world (Table 9-1). Ratites lack a keel, and as the need for flight is absent, ratites lack clavicles (except emus) and triosseus canals, the thoracic girdle is modified by fusion of scapula and coracoid, and the only pneumatized bone is the femur in ostriches and emus. The wings are vestigial and carry variable numbers of claws (two in ostriches, one in rheas, none in emus and cassowaries) and are used for balance and display behavior. Ratites have long, heavily muscled legs, which enable them to run at high speeds; they also use their legs for defense and offense, kicking forward, with cassowaries using both feet at once. Ratites lack a patella. Whereas emus, cassowaries, and rheas have tridactyle feet with a nail on all toes, the ostrich only has two toes (didactyl) with a nail on the larger, medial toe only. Cassowaries carry a daggerlike, dangerously sharp claw on the inner toe. Kiwis have a small fourth toe pointing caudally with a spurlike nail.[18,19,52,53]

TABLE 9-1

Morphologic and Reproductive Aspects of Ratites

	Ostrich	Emu	Rhea	Cassowary	Kiwi
Size (m)	2.5–3.0	1.5–1.8	1.5–1.7 (Common> Darwin's)	1.7–2.0	0.3–0.6
Max. weight (kilogram [kg])	120–160	38–55	25	60–85	1–4
Gender size	M > F	F > M	M > F	F > M	F > M
Breeding strategy	Polygamous	Paired for breeding	Polygamous	Paired for breeding	Paired for life
Eggs No/female/year	<100	7–20	10–15	3–6	1–3
Color	cream	dark green granular	yellow- greenish	light, bright green	white
Weight	1–2 kg	500–700 grams (g)	400–600 g	600–700 g	400–500 g
Incubation (days)	39–44	56–61	39–42	60	71–78 (–92)
Incubating partner	M (night), F (day)	M	M	M	M
Parental care	M (+F), 1 year	M	M, 4–6 months	M	M (+ F)

M, Male, *F,* female.
From Del Hoyo J, Andrew E, Sargatal J: Order Struthioniformes. In Del Hoyo J, Elliott A, Sargatal J (eds): *Handbook of the birds of the world*, Volume 1, Barcelona, Spain, 1992, Lynx Editions.

In ratites, the barbules, although present, do not interlock, giving the ratite feathers the particular fluffy appearance sought after for decoration and fashion.[18,19] Feathers of the emu and cassowaries have a double shaft.[53] Down feathers are rare or absent, and ratites continuously molt. The plumage of kiwis has a shaggy appearance because of the hard, hairlike, waterproof distal ends. Cassowaries have a unique protuberance on the head, called *casquet* or *helmet*. Brightly colored wattles are only present in the Northern and Southern species and likely function as a social signal.[19,41,53]

The respiratory system in ratites is comparable with that of other avian species with 10 air sacs.[6,7] In the emu, the complete cartilaginous tracheal rings in the distal trachea are interrupted by a 6- to 8-cm long ventral cleft, where a thin membrane forms a large, expandable pouch to produce the characteristic booming sound.[19,52,53] Respiration rates of ostriches fall within two ranges, either within a low range of 3 to 5 breaths per minute (breaths/min) or a high range of 40 to 60 breaths/min when panting in response to heat stress.[53] Ratites have a slightly lower core body temperature compared with other birds; kiwis, especially, have a low average basal temperature of 38° C, approximating that of mammals.[47]

All ratites lack a true crop, but considerable differences exist in the musculature and enzyme secretory function of the gastric compartments and characteristics of the intestinal tract, reflecting adaptations to different diets.[18,52,53] Having adapted to a rough, fibrous diet, both ostriches and rheas rely on a small glandular patch in the proventriculus but show a large, thick-walled ventriculus with a distinct koilin layer. Other than in the rhea, in which the proventriculus is significantly smaller than the ventriculus, both compartments are similarly sized and connected by a large, rather indistinct sphincter in the ostrich and small stones for grinding are physiologically found in both compartments. Ostriches show a unique arrangement of the two gastric compartments, with the thin, saclike proventriculus taking a turn and the gizzard being located cranioventrally. Whereas the rhea largely depends on enormous paired ceca for effective hindgut fermentation, the ostrich has a particularly voluminous colon and long rectum and relatively smaller ceca. Spiral folds within the cecal lumen provide an increased surface area for fermentation. Following the adaption to a more nutritive and less fibrous diet, the proventriculus in emus and cassowaries is comparably large and diffusely glandular, whereas the small ventriculus is thin walled and lacks a koilin layer altogether in the cassowaries. The paired ceca in emus and cassowaries are vestigial and of minor functional importance, particularly in the cassowary. The gastrointestinal (GI) passage time is approximately 48 hours and 18 hours in ostriches and rheas, respectively, but only 7 hours in emus.[53] In all ratites, a particularly strong rectal–coprodeal sphincter results in separate defecation and voiding of urine: feces are stored in the rectum, whereas urine is mainly stored in the proctodeum, which acts as "bladder."[18] Ratites lack a true bursa; instead, the bursa of Fabricius in the ostrich and emu forms an integral part of the dorsolateral wall of the proctodeum. No gallbladder exists in the ostrich, but one is present in the other ratites.[53]

Male ratites have an intromittent reproductive organ. In adult ostrich males, the flaccid phallus is up to 20 cm long and lies folded in a phallic pocket in the ventral wall of the proctodeum; when erect, it may reach a length of 40 cm and physiologically deviates to the left.[18,53] It serves to transport sperm via a dorsal sulcus (in the ostrich and kiwi) or a central cavity (in the rhea, emu, cassowary) but has no urinary function.[53] Manual gender determination may be easily conducted in young birds at 1 to 3 months: the clitoris and the phallus are similarly sized but differ in shape and in the presence of the seminal groove.[18] Female reproductive organs are similar to those of other avian species; usually only the left ovary and oviduct develop.[53] Kiwis, however, are among the very few avian species with paired ovaries.[29]

Although the larger ratites have acute eye sight,[53] the nocturnal kiwi mostly relies on its strong sense of smell with its nostrils at the distal tip of the beak and excellent hearing, as evidenced by large earholes. Kiwis lack a pecten, and their vision is rather poor.[19]

Special Housing Requirements

Ostriches and, to a lesser extent, emus and rheas are reared as farm animals for meat, feathers, and hides in Africa, Europe, Australia, and South and North Americas.[18,19,52] Ostriches and rheas may be kept in large groups; however, during breeding season, males become territorial, so harem groups are advisable.[18] Emus are usually kept in pairs. In zoologic institutions, ostriches, rheas, and emus are commonly included in multispecies exhibits with other herbivores. In the wild, ostrich groups move and feed with herds of hoofstock, but they tend to avoid close contact with other animals. If startled or challenged, ostriches may react with panicky escapes; therefore, exhibits need to provide sufficient space and structures to allow avoidance or flight behavior. Barriers have to be easily visible, as ostriches, emus, and rheas tend to get entangled and caught in piles of branches, wires, and dry moats. Large ratites are usually kept in open paddocks and fenced pastures.[18] Ratites need indoor enclosures or at least dry shelters to be protected against wind and precipitation. They may tolerate cold temperatures and even snow for short periods, but they are sensitive to cold-wet conditions.[45] As waterproofing is impossible because of the lack of interlocking barbules, ratites get sodden in rain, and they lack down feathers for insulation.[19] Indoors areas with heated or at least well-insulated flooring are imperative for hatchlings and juveniles.[18]

Cassowaries may also be kept in pairs and may tolerate each other, but it is advisable to keep them separate for incubation of the eggs and rearing of the chicks.[23,41] Keeping kiwis in captivity is not easy; usually, only the Brown Kiwi is kept in zoologic institutions but is very rarely bred. Kiwis are to be kept in pairs as they take mates for life. Deep earth floors for burrowing, high humidity, and dense vegetation are important factors in their exhibit.[19]

Feeding

Ostriches and rheas are exclusively vegetarian and selective grazers with very efficient fiber utilization in postgastric microbial fermentation. Green annual grasses and forbs are preferred, although leaves, flowers, fruit from succulent and woody plants, and, rarely, insects and small invertebrates are also consumed.[18,19] Because of the economic interest in ratite farming, a large body of information on the nutritional requirements of ostriches is available. Complete diets are commercially available in pelleted form, which should be supplemented with high-quality roughage and vegetation for adequate fiber intake and enrichment.[13,52,53] Having adapted to an arid environment, absence of drinking is possible in adult ostriches, rheas, and emus if succulent food is fed, but reduced weight gain and impaired reproduction are often caused by inadequate water supply.[19,52] Emus are omnivorous but show a highly selective behavior for nutritious food items. In the summer time, a large part of their diet consists of insects.[19] Cassowaries are largely frugivorous but may also consume fungi, insects, and small vertebrates.[41] Wild kiwis consume almost exclusively invertebrates from the forest floor, but their captive diets are generally meat and fruit, with much higher carbohydrate and water content and lower crude fat compared with the diet in the wild.[19,39]

Restraint and Handling

While chicks and kiwis may easily be restrained manually, catch pens or chutes are most appropriate for adult, large ratites. Ratites jump, kick, and slash in a forward direction; therefore, manual restraint of large ratites may be dangerous and requires experienced personnel.[47,52] The risk of injury from the daggerlike claw does not allow for manual restraint of adult cassowaries.[47] Ostriches, emus, and rheas may be approached from behind or the side. At least three people are needed to handle an adult bird, but care needs to be taken not to grab the bird by the neck (neck hooks are not recommended), the legs, or the vestigial wings or to interfere with respiration during straddling.[47,52,53] In ostriches, lowering the head quickly to the ground prevents them from kicking, and they may even assume sternal recumbency. Darkness has a calming effect on ratites, and hooding is one of the best aids to handle manually restrained ostriches.[52] Other ratite species are less tolerant of hooding, and the effect is unpredictable.[53] As ratites are prone to exertional myopathy, chemical restraint is advisable for any longer procedure to reduce stress and risk of injury to birds and handlers.[52]

Whereas most other birds and chicks are not recommended to be fasted for anesthesia, adult large ratites may be fasted for 12 to 24 hours and water withheld for up to 4 hours prior to anesthesia to reduce the risk of regurgitation and aspiration.[42,52,53] Chicks and kiwis are usually just manually restrained for induction via face mask and maintained, ideally intubated, on isoflurane inhalation. For remote injection of anesthetic drugs in larger birds, the ideal dart placement is perpendicular into the proximal thigh muscle.[53] Underdosing may result in overexertion during the excitatory phase and should be avoided. Benzodiazepines (diazepam or midazolam 0.3 to 1 milligram per kilogram [mg/kg]) and α_2-agonists (xylazine 0.2 to 3 mg/kg, medetomidine 0.05 to 0.5 mg/kg) are commonly used alone or in combination with butorphanol (0.1 to 0.2 mg/kg) for sedation and premedication, but times to effect and efficacy are highly variable and depend on the disposition of the bird.[42,52,53] Ketamine (3 to 20 mg/kg) or telazol (2.3 to 4.9 mg/kg) are commonly used as induction agents but need to be combined with benzodiazepines or α_2-agonists to prevent muscle rigidity and rough induction and recoveries.[47,53] Injectable agents rarely provide anesthesia of sufficient duration for longer procedures, and inhalants (usually isoflurane) are commonly used for maintenance.[42,52,53] Intubation is achieved easily with the tracheal opening readily visible at the base of the tongue.[47] The unique tracheal cleft in emus necessitates wrapping of the lower neck with an elastic bandage to avoid insufflation of the pouch.[47,53] Alternatively, intravenous (IV) maintenances on a triple-drip combination (ketamine, xylazine, and guaifenesin) or propofol infusion are described in the literature.[47] Ratites appear rather refractory to the sedative effects of potentiated opioids but show excessive running or frenzied activity during the excitatory phase and apnea during anesthesia.[47] However, combinations of thiafentanil, α_2-agonists, and telazol have shown promising results in emus and rheas.[6,17,38]

Monitoring via pulsoxymetry is possible on the ulnar vein or intermandibular tissue.[47] Supplementation of vitamin E or selenium, nonsteroidal anti-inflammatory agents, and adequate infusion therapy may be advisable to prophylactically address exertional myopathy.[47] Recovery should occur in a dark, padded room, or the birds need to be supported until they are able to maintain normal head position. Sternal recumbency is not a problem, but lateral recumbency over a long time might result in peroneal nerve paralysis, so careful padding is crucial.[53] A body wrap may help to control the recovery process.[52] Haloperidol administration achieved long-term sedation in adult ostriches for transport and reduction of aggression, lasting for 20 hours.[38] For short transports, azaperone is useful as it provides little muscle relaxation but good tranquilizing effects for up to 24 hours.[47]

Surgery

One of the most commonly described surgical interventions in ratites is proventriculotomy to address gastric impaction and ingestion of foreign bodies.[3,33,52,53] Juvenile ostriches are most commonly affected, but cases in juvenile rheas and an adult kiwi have been reported.[24,25] The proventriculus in ostriches is palpated in the left paramedian quadrant over the xiphoid. A left lateral approach over the proventriculus is preferred. Failure to adequately absorb the yolk sac may necessitate removal of the yolk sac in chicks, which is usually performed with a ventral midline approach, cranial of the umbilicus to beyond the extension of the yolk sac.[52,53] After excising the umbilical cord, the yolk sac is lifted out of the coelomic cavity and the duct ligated. Any spillage of yolk requires vigorous rinsing with warm saline. As in all other birds, egg binding may have to be addressed surgically, and castration of male ratites has been performed successfully.[18,53]

Wound management and orthopedic surgery are commonly necessary, as traumatic injuries are frequent in ratites.[52,53] These procedures follow the same principles as in any other species, considering the requirements to support heavy weights and bipedal locomotion in these large and rather nervous animals.[52]

Other Pharmaceuticals

In most countries, no drugs have been licensed for ratites, and chemical therapeutics need to be used in an off-label manner compatible with the local veterinary authority guidelines. Because of the lack of large pectoral muscles, the preferred injection sites in ratites are the epiaxial or proximal leg muscles.[53] IV access is possible at the right jugular vein and medial metatarsal or ulnar veins. If IV access is not possible, intraosseous catheters in the ulna or tibiotarsus may be placed in juvenile birds.[47] Only few pharmacokinetic studies in ratites exist, and most drug therapies are extrapolated from commonly known avian dosages. However, several studies found differences in the pharmacokinetic profiles not only between ostriches and other avian species but also between emus and ostriches. Therapeutic success should therefore be carefully monitored and evaluated.[11,53]

Physical Examination and Diagnostics

Blood sampling is, as in most avian species, most convenient from the large right jugular vein of the neck or the medial metatarsal vein in young or anesthetized adult birds.[18,52] Because of the highly movable skin along the neck, placement of a permanent catheter into the jugular vein may be very difficult, and the ulnar or medial metatarsal veins are preferred for IV catheters.[53] Lithium-heparin or citrate should be used as anticoagulants, as EDTA (ethylenediaminetetraacetic acid) causes hemolysis.[18,53] Reference ranges for blood values are comparable with those in other avian species but vary considerably in the literature; single samples may, therefore, be difficult to interpret, and trends in multiple, sequential samples are most useful to evaluate the progress of disease in an individual bird.[18,52,53] Physical examination in ratites is similar to that in other avian species.[53] Ratites are very sensitive to stress-associated diseases, so careful risk assessment of the necessary diagnostic steps and treatments is necessary. Full body survey radiographs (e.g., for suspected gastric impaction) are best accomplished with large ratites standing, either sedated or hooded in manual restraint, with a horizontal beam against a radiographic plate attached to the wall.[52]

Disease—General

Increased demand of ostrich products and worldwide ostrich trade in the 1990s raised the question of their disease status regarding poultry diseases (e.g., avian influenza, Newcastle disease) and led to the legal classification of ostriches as "poultry" in most jurisdictions with application of the same restrictions.[2] Most diseases in ratites are, therefore, described for the economically interesting species such as ostrich, emu, and rhea. For cassowaries and kiwis, not many publications are readily available, but both species appear susceptible to the same types of diseases that are described for other ratites and avian species. Exceptions are discussed below.

Infectious Disease

GI infections are very common in chicks and juvenile ratites. Yolk sac retention and infection is a multifactorial disease causing mortalities in chicks up to 2 weeks of age.[21] Source of infection either originates from egg contamination or naval infection. *Escherichia coli* is often involved and responds poorly to antibiotics, necessitating surgical removal or aspiration of the yolk.[18,22,52,53] Enteritis in chicks and juveniles is often caused by failure to establish a balanced gut flora, the use of antibiotics, lack of fibers in the diet, hypothermia, excessive coprophagy, and poor hygiene. A multitude of bacterial pathogens such as pathogenic strains of *E. coli*, *Salmonella* spp., *Klebsiella*, *Aeromonas* sp., *Pseudomonas sp*., and certain strains of *Campylobacter jejuni* (enteritis, hepatitis in chicks) and *Clostridium perfringens* may be involved.[15,18,44,52,53] Spirochete-associated (*Serpulina hyodysenteriae*) necrotizing typhlitis was diagnosed most frequently in young rheas in summer and fall.[28,53] Viral (avian influenza virus, coronavirus, rotavirus) or protozoal pathogens (cryptosporidia, *Histomonas meleagridis*) have also been identified in ratites with GI problems.[15,18,53] Fungal proventriculitis and ventriculitis are common sequelae to gastric impaction, and *Macrorrhabdus ornithogaster* has caused severe losses in juvenile ostriches.[15,18,26,53]

Respiratory diseases are commonly caused by infections with *Pasteurella* sp., *Pseudomonas* sp., *Bordetella* sp., *Haemophilus* spp., *Staphylococcus* spp., *Streptococcus* sp., *Corynebacterium* sp., *Mycoplasma* spp., and *Chlamydophila psittaci* in predisposed birds because of hypothermia, stress, and overcrowding, or poor air quality.[18,44,52,53] Respiratory aspergillosis caused by *Aspergillus fumigatus* and other *Aspergillus* spp. is a common problem in juveniles or compromised adults in stressful or suboptimal management conditions.[15,18,52,53] Antifungal prophylaxis should be considered during antibiotic treatment or stressful situations such as transports and translocations.

Acute deaths in juvenile emus from *Erysipelothrix rhusiopathiae* septicemia has been reported several times. The disease could be controlled with antibiotic treatment, improved husbandry management, and annual vaccination of birds.[49,53] The ostrich is the only avian host susceptible to *Bacillus anthracis*, but cases have become extremely rare.[49,53] Mycobacteriosis, commonly caused by *Mycobacterium avium*, occurs occasionally in zoo ratites but is very rare in farms. It is hardly ever a herd problem but often affects individual birds; however, because of the theoretical zoonotic potential, this pathogen has attracted a lot of attention. Clinical signs either reflect localized lesions (granulomatous lesions at conjunctiva, cloaca, phallus) or generalized infection (GI, liver) in which the animals slowly waste away. Culture and polymerase chain reaction (PCR) assay on tubercles is considered the gold standard diagnosis, but as no effective treatment exists, affected birds should be culled.[15,53]

Cryptococcus neoformans var. *gattii* (serotype B) was identified in a kiwi with disseminated infection in the heart, kidney, liver, oviduct, and pancreas. Eucalyptus mulch was thought to be the source of infection. Because of their lower body temperature compared with other birds, kiwis are thought to be more susceptible to cryptococcosis.[27]

Ostriches, emus, and rheas are among birds that are highly susceptible to avian influenza, and various strains have been identified in ratites, including H7N1, H5N9, H5N2, H9N2, and H10N7. The pathogenicity in ratites depends on the viral strains, with particularly high mortality reported in H7N1 outbreaks among juvenile ostriches. Chicks are more susceptible than adults, and secondary bacterial respiratory and intestinal infections sometimes mask the underlying viral infection.[12,52] Despite the highly contagious nature of avian paramyxovirus serotype 1 (Newcastle disease) during an outbreak, chronic neurologic disease in ostriches tends to spread relatively slowly through the population, is usually limited to a small number of birds (mostly juveniles), and may therefore be controlled with vaccinations. Emus have tested serologically positive, but no cases of clinical disease have been described.[2,12,30,52] In contrast to the pathogenesis in most other avian species, eastern equine encephalitis virus does not cause neurologic disease in emus and rheas but shows a unique visceral tropism, primarily leading to GI symptoms.[52,53,55] Avian poxvirus may manifest as either wet or dry forms. Vaccination with fowl pox vaccines has proven effective in ostriches.[12,52,53] Bornavirus infection has been reported to have resulted in outbreaks of paresis and general malaise, followed by anorexia, depression, and death from dehydration in ostrich chicks in intensive farming conditions.[12,53] Both adenovirus and circovirus were isolated from sick ostrich chicks and were suspected to be implicated in the "chick-fading syndrome."[22,40,53] Miscellaneous viral pathogens reported in ratites include infectious bursal disease virus (only experimental disease, no natural infections reported),[35,53] rotaviruses, orthoreoviruses, and reoviruses (serologically positive samples or viral isolation, but clinical relevance remained unclear),[18,53] and Crimean-Congo hemorrhagic fever (CCHF), a tick-transmitted disease occurring across the African continent, that causes a short, symptomless viremia in sheep, cattle, and ostriches and has fatal zoonotic potential (through handling of tick-infested ostriches or through contact with infected ostrich blood during slaughter).[12]

Two cases of spongiform encephalopathy in adult ostriches in German zoos have been histologically described, but the etiology was never confirmed with electronmicroscopy.[18]

Parasitic Disease

A range of endoparasites were identified in ratites, of which GI nematodes are of most significant clinical importance, as they cause economic losses in ratite farming.[18,36,53] In ostriches, the trichostrongylid nematodes *Libyostrongylus douglassii* (most common), *L. dentatus,* and *L. magnus* are found in the openings of the deep proventricular glands and under the koilin layer of the proventriculus and the gizzard. Heavy parasitic load may lead to proventriculitis with associated weight loss and anemia and to high mortality in chicks and juveniles.[15,18,36,53] The parasite appears to be rather host specific but may infect other ratites such as rheas. Similarly, in rheas, *Sicarius uncinipenis*, a reddish worm, inserts itself between the koilin layer and the ventricular mucosa and leads to destruction of the koilin layer.[53,56] In addition, the large-intestine nematodes

Paradeletrocephalus minor and *Deletrocephalus dimidiatus* are considered to be of some relevance because of their blood-feeding habits, which may, in high infections, be associated with an anemia syndrome in rheas.[36,56] *Trichostrongylus tenuis* has been found in the ceca of emus, and pathogenicity is comparable with that in game birds. A low burden might remain clinically unapparent, but large numbers of parasites may result in bloody diarrhea, progressive anemia, and toxemia.[36,53] *Codiostomum struthionis* is a slightly larger helminth, which inhabits the distal cecum and upper rectum of adult ostriches but is mostly clinically inapparent.[18,36,53] *Houttuynia struthionis* is a large tapeworm, which inhabits the small intestine of ostriches and rheas, causing ill-thrift in young ostriches.[15,18,36,53] *Fasciola hepatica* has been associated with subacute and chronic hepatitis in emus. Antiparasitic treatment with triclabendazole may be necessary in severely affected birds, and separation of hoofstock carriers and pasture management are recommended. Although no reports of clinically apparent fasciolosis exist, chronic fasciolosis was identified in the livers of healthy slaughtered rheas.[36,54] The finding of extraintestinal filarial worms (*Dicheilonema rhea, D. spicularia, Contortospiculum rhea, Paronchocerca struthionis, Struthiofilaria megalocephala*) in the coelomic cavity, musculature, lungs, and air sacs of ratites is, however, mostly incidental. Attempted antifilarial treatment may be detrimental because of the immune response to the dead parasites.[53] *Syngamus trachea* and *Cyathostoma variegatum* have been found in apparently healthy ratites, but high parasitic burden and accompanying stressors may lead to respiratory clinical signs, especially in juvenile birds.[36,52,53] Fatal cerebral nematodiasis caused by *Baylisascaris procyonis* and *Chandlerella quiscalis* larvae migrans are primarily reported in emus and ostriches but also occasionally in other ratites in North America. Songbirds are the reservoir for *C. quiscalis*, and the parasite is transmitted by Culicoides mosquitoes, whereas *B. procyonis* is harbored by raccoons and directly transmitted from raccoon latrines near ratite enclosures. Prophylaxis with oral ivermectin, fenbendazole, or pyrantel tartrate is recommended in endemic areas.[10,15,53]

Cryptosporidium sp. are specific to ostriches and infect the bursa, rectum, and pancreas, causing severe chick losses in farms in South Africa.[36] Although coccidiosis is common in emu chicks, no clinical cases have been reported in ostriches.[36] *Entamoeba struthionis* is highly prevalent but nonpathogenic, and *Balanthidium struthionis* cysts may be confused with coccidial oocysts.[18,36] *Histomonas meleagridis* derived from poultry may cause similar disease (typhlohepatitis) in ostriches.[36,53] *Toxoplasma gondii* serology studies revealed only a rare risk of disease despite potential susceptibility.[20] Coccidiostats in ratite rations are not recommended and possibly also dangerous, as some of the ionophore coccidiostats are toxic for ratites.[18]

Ectoparasites such as feather lice (*Struthiolipeurus struthionis, S. rheae*), thribs (*Limothrips denticornis*), and quill mites (*Gabucinia* spp., *Struthiopterolichus* sp.) may cause pruritus, cellulitis, excessive pruning, and feather and skin destruction.[15,36] Hippoboscid flies (*Struthiobosca struthionis)* may be the cause of considerable irritation and act as disease vector.[18] A number of ixodid ticks are known to infect ostriches, and their potential to transmit diseases needs to be considered.[53]

Antiparasitic treatment in ratites follows the principles of treatment in other avian species. However, toxicologic side effects have been noted with several products, and the reader is referred to the toxicology section.[15]

Noninfectious Disease

"Chick fading syndrome" is a multifactorial disease complex that relates to improper incubation and rearing techniques and possibly viral infections.[18,22,40,53] Affected chicks often hatch with increased generalized edema, are weak, are reluctant or unable to exercise, and show delayed or inappropriate intake of food. Subsequent problems such as yolk sac retention and infection, leg deformities, gastric stasis and impaction, and secondary infections are responsible for major mortalities in 1- to 3-week-old chicks.[18] Cloacal prolapse in less than 3-month-old chicks is often associated with insufficient hydration and enteritis and may be treated with reposition of the cloaca followed by purse string suture and supportive care.[44]

Deformities of legs are identified as one of the most important constraints to farm ostrich production but also happen in other ratites. Tibiotarsal rotation, rolled toes, slipped tendons, and bowed legs appear at different stages of growth, and the multiple etiologic factors include protein content of feed and other nutritional factors (minerals, trace elements), trauma, flooring (pen design), inadequate exercise, availability of water, and genetic predisposition. Rolled toes happen by medial displacement of the toe pad and happen most frequently in chicks less than 2 weeks of age. Vitamin B deficiency was hypothesized on the basis of "curled toe paralysis" syndrome in poultry, but the pathogenesis differs. Splinting and trimming nails work in most cases, but often spontaneous resolution also occurs by the age of 4 weeks. Tibiotarsal rotation and bowed tarsometatarsal bones occur in 2-week to 6-month-old chicks and may be caused by an inappropriate diet (high protein; excessive vitamin supplementation; deficiencies of calcium, manganese, and niacin), and rapid early growth rates. Slipped tendon corresponds to lateral displacement of the gastocnemius tendon of the tibiotarsometatarsal joint mostly in older chicks or the Achilles tendon medially over the tarsometatarsophalangeal joint in younger birds, often because of abrupt movement ("waltzing"). Similarities to perosis in poultry because of magnesium deficiency have not been proven.[18,41,44,53]

Gastric impaction is another common disease of juvenile ratites less than 6 months old and appears to be stress related. Impaction of the proventriculus with foreign body material because of abnormal compensatory picking (disorientation stress, desertion stress, or frustration with regard to finding food from change of location or diet), with or without stasis of the ventriculus with accumulation of natural substrates, and koilin hypertrophy frequently occur simultaneously, and the clinical signs and treatment are identical. Clinical signs are nonspecific (loss of appetite, lethargy, weight loss, dehydration, scant defecation), and successful treatment depends on early recognition of the syndrome; regular weight checks, serial contrast radiographic examinations, and auscultation and palpation of the left cranial quadrant after withholding food for 12 hours are the helpful measures.[18,44,46,53] If impaction is suspected, medical treatment may be tried with high-energy liquid (vegetable oil), gastric lavage and emulcents and laxatives, metoclopramide, and systemic antibiotics.[3] However, if no improvement is seen in over 24 hours or presence of foreign bodies is confirmed radiologically, surgical intervention (proventriculotomy) is mandatory and has a good prognosis if attempted early. As birds mimic each other's behavior, all birds must be checked if one bird is affected.[33,52]

Nutritional diseases include obesity; metabolic bone disease in chicks; white muscle disease induced by vitamin E or selenium deficiency; vitamin B (pantothenic acid) deficiency caused by high grain rations, resulting in retarded growth and skin crust formation on eyelids and corners of the beak; vitamin A deficiency in rheas, associated with runny eyes, abscesses, on the palate, and stunted growth; and vitamin E–associated encephalomalacia in emus, resulting in neurologic disease and sudden deaths.[4,18]

The excitable disposition of ratites predisposes them to capture myopathy after exertion, heat, recovery from anesthesia, and entrapment. Treatment is rarely successful, but one report describes successful treatment of a rhea with IV fluids, esophagostomy-tube feeding, long-term sedation, treatment with muscle relaxants, dexamethasone, and antibiotics, and sling and physiotherapy, all resulting in resolution after 23 days. Proper management, restraint, transport, and capture techniques are important preventive measures.[47,48,50]

Female reproductive tract infections and egg binding are important causes of poor fertility in captivity.[53] Transcutaneous ultrasonography is a useful noninvasive technique to monitor ovarian (in)activity and to diagnose reproductive pathologies, with the probe placed directly behind the thigh on the ventrolateral, featherless part of the abdomen.[8]

Miscellaneous conditions include trauma to neck and legs,[52,53] subchondral cysts, bone sequestration, and arthritis as a cause of lameness in ostriches and emus,[9,51] phallus prolapse and lesions and testicular cysts in adult males,[1,53] aortic dissection and aneurysm,[5] a hereditary form of neuronal gangliosidosis in emus,[7] behavioral abnormalities (excessive feather pecking, stargazing in close confinement, imprinting on humans),[43] and a most likely genetically related, noncontagious, mechanobullous skin disorder with skin sloughing and coagulative skin transudate in juvenile ostriches.[37]

Toxicities

Drug-related toxicities have been reported from lindane-containing antiparasitic products (benzene hexachloride, morantel), ionophore coccidiostats, lincomycin, dynamulin, streptomycin, and colistin antibiotics.[18] Selenium toxicities from oversupplementation has resulted in high mortality in ostrich and emu chicks.[32] Ingestion of parsley was associated with photosensitivity, avocado with epicardial edema and myocardial degeneration, acorns with enteritis, and oak leaves with fatal nephritis (cassowary).[18,31] Fungal toxins such as sporodesmin and aflatoxin in moldy feed lead to liver damage and immunosuppression. *Clostridium botulinum* toxicities (from occasional intake of bones, carcass in hay) were associated with paralysis in wild ostriches.[18] Their curious nature and long necks predispose ratites to accidental intoxication with pest control agents such as rat poisoning (anticoagulant warfarin).[18]

Reproduction

Differences in reproduction between the five ratite species are listed in Table 9-1.[18,19] Male ostriches sexually mature at 4 to 5 years of age and the hens slightly earlier, and they remain reproductive for up to 40 years. Their sexual activity is seasonal and associated with the photoperiod, rainfall, and availability of food. Males become territorial during the breeding season and display an impressive courtship behavior. Territorial males dig shallow nest scrapes, in which several visiting females contribute eggs to a communal clutch, leading to multiple maternity and paternity in one clutch, but only the “major” female and the resident territorial male provide incubation and parental care. More eggs (40–60) are laid in the nest than may be incubated, and the major female ejects surplus eggs from the incubated central clutch of approximately 20. Incubation is carried out by both genders, with the male bird mostly sitting during the night. Hatching in the nest occurs after average incubation duration of 42 to 43 days and over 4 to 5 days. Parental care is provided by both parents, and chicks are abandoned at the age of 1 year.[18,19,53] Ostrich eggs are unusual for their large size and low shell conductance, which makes them prone to insufficient water loss and results in edematous and malpositioned chicks.[18] The ostrich has been farmed for over 100 years, and the production has gained global importance in the past few decades. The main constraints of the ostrich production are high rate of infertility, low hatchability, and post-hatch problems such as leg deformities and fading chick syndrome.[18,53] As a consequence, a wealth of literature on ostrich production is available, and the reader is referred to it. Briefly, artificial incubation protocols consist of preincubation storage of the eggs at approximately 20°C for 7 to 10 days, incubation at temperatures of 36°C to 36.5°C and comparably low humidity at 20% to 25% to reach 8% to 18% loss of egg weight until pipping. Vertical position of the eggs during incubation appears beneficial, and frequent turning of the eggs is crucial.[16,53] Sperm collection and artificial insemination have been attempted but are not commonly practiced.[42]

Like ostriches, rheas practice polygamous reproduction, with one male competing for several females to lay eggs in a communal nest. Parental care is performed exclusively by males, with females restricting their investment to the production and laying of eggs.[19]

Although kiwis pair for life, emus and cassowaries only pair for the breeding season.[19,23,41] Incubation and rearing of chicks is performed exclusively by the males in all three species; however, kiwi females may be partly involved.[19] Kiwis have the largest egg-to-body ratio, with eggs reaching up to 20% of the female's body weight.[29] The clutches are considerably smaller (2–3 eggs) and incubation time significantly longer (63–92 days) than in other ratites.[19]

Preventive Medicine

Quarantining new birds for at least 30 days, fecal parasitologic examinations, and serologic testing for avian influenza and Newcastle disease are, if not mandatory per regulations, strongly advised.[18,52,53] Although no vaccinations are licensed for use in ratites, the use of commercial vaccines for domestic hoofstock and poultry against enterotoxemia (clostridial toxins B and D), *Mycoplasma gallisepticum*, anthrax, Newcastle disease, avian pox, and avian influenza have shown promising results and may be advised in endemic areas. Tick and rodent control should be part of the routine prophylactic measures.[52,53]

TINAMOUS (ORDER TINAMIFORMES, FAMILY TINAMIDAE)

Biology and Reproduction

Tinamous are exclusively neotropical, medium-sized, plump, terrestrial but nonetheless flighted birds. As one of the oldest avian families in the New World, they are thought to come from the same stock as the Struthioniformes. The close relationship between ratites and tinamous is reflected in similarities in bone structures (especially the palate), eggshell structure, and thermoregulatory and metabolic physiology. The subfamily Tinaminae (forest tinamous) includes 29 species, which are primarily found in tropical and subtropical forests and are differentiated from the second subfamily Rhynchotinae (steppe tinamous, 18 grassland species) by the presence of nostrils in the distal half of the bill. Tinamous are shy and elusive birds and good runners when startled. Their diet is extremely variable and opportunistic, including plant material (fruit, seeds, leaves, flowers, roots), invertebrates, and small vertebrates. Forest dwelling species generally have a larger part of fruit in their diet, whereas grassland species take a greater proportion of seeds.[19,34]

During breeding season, males attract several females to lay eggs in a communal nest on the ground. The male solely takes care of incubation and rearing of the chicks. Tinamous eggs are elliptical to spherical, shiny, and uniformly but brightly colored in varying colors, depending on the species. Clutches contain up to 16 eggs, and incubation is relatively short (16–20 days). The precocial chicks become independent from the male's care within 10 to 20 days, and sexual maturity is reached at approximately 1 year of age.[19]

Anatomy

The external appearance of tinamous closely resembles that of Old World partridges or pheasants, reaching 15 to 50 centimeters (cm) in height and 50 to 1800 grams (g) in weight, depending on the species. Similarly, the wings are small in relation to the plump body. The tail is rudimentary and useless for steering, so flight cannot be kept up for long distances and does not appear particularly coordinated. Tinamous feathers have a unique structure, with the barbules being joined together in a solid mass and producing a whistling noise during flight. Feathers on the back and rump are easily shed as a defensive measure. Unlike Struthioniformes, tinamous have highly developed powder-downs for waterproofing the feathers. Females of some species are more brightly colored than males and are heavier. Tinamous have three forward facing toes and one absent or rudimentary hind-toe, and some species may be differentiated by the colors of the tarsi.[19]

Diseases

Reports on captive and wild tinamid diseases are scarce, with a limited number published in Portuguese. The few captive populations are mostly in private hands, and veterinary monitoring has been poor. A recent health survey in private collections in Brazil revealed a small percentage of animals serologically positive to infectious bursal disease virus.[34] All animals were serologically negative to avian paramyxovirus serotype 1; however, in an experimental study, experimental and natural seroconversion was shown. Serology results for *Mycoplasma gallisepticum* and *M. synoviae* were variable, depending on the tests, or negative. Despite serologically positive birds for *Salmonella pullorum* and *S. gallinarum*, bacteriologic examinations were negative. Fecal examinations revealed *Capillaria* spp., *Eimeria rhynchoti*, *Strongyloides* spp., *Ascaridia* spp., and unknown sporozoa and several louse species that were externally parasitizing on the animals.[34]

ACKNOWLEDGMENTS

The author thanks Dr. Dale Smith and Dr. Pia Krawinkel for their valuable contributions to this chapter.

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