

A brief report on the development of dorsal air sacs in hand reared Von der Decken's hornbills (*Tockus deckeni*)

Avian Biology Research
2020, Vol. 13(4) 87–91
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DOI: 10.1177/1758155920951685
journals.sagepub.com/home/avb



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Abstract

Several species of hornbills are known to develop dorsal air sacs after hatching, which present as a pocket of air under their skin. These increase in size as the chicks grow, and gradually disappear as the chicks develop feathers. However, this feature is not well-described, nor do we know the extent it occurs in Bucerotids. Here, it is reported in a clutch of hand-reared Von der Decken's hornbills (*Tockus deckeni*) ($n=5$) at Jurong Bird Park, Singapore. Air sacs were not present at hatch, but developed within 24h, increasing in size until about 10 days of age. They gradually recede from this age and are not always inflated, disappearing at about 16 days of age when the chick has considerable feather growth. The functions of this unique feature are largely unclear, but it is thought to be mostly related to thermoregulation. Further research is required to determine this, possibly using captive specimens from zoological institutions as it is more difficult to collect data from wild birds.

Keywords

Thermoregulation, air sacs, anatomy, hornbills, Bucerotidae

Introduction

The presence of dorsal subcutaneous air sacs in hornbill chicks is suggested to be a unique feature to the Bucerotidae,^{1–4} but it has not been widely described. These air sacs appear as a pocket of air under the skin of the chick, developing over the shoulders and back. The functions of these structures remain largely unconfirmed. Female hornbills seal themselves inside natural nest cavities, while the male supplies food for her and their nestlings through a small opening.^{5,6} The female usually only emerges after the chicks are fairly well-developed.^{5,6} Thus these structures are believed to provide pneumatic protection to cushion chicks in a crowded, cramped nest⁷ and also to aid in thermoregulation.^{8,9}

This structure has also been referred to as 'normal' subcutaneous emphysema,¹ a term mostly used to describe a condition in birds where air escapes from the respiratory system due to trauma and/or injury, and accumulates in the subcutis, inflating the skin. However, besides its location in the subcutis, these air sacs are not connected to the respiratory system.⁸

The extent to which this feature exists in the family is unclear. It has been described as early as the 1970s, in wreathed hornbills (*Rhyticeros undulatus*), rhinoceros hornbills (*Buceros rhinoceros*), great hornbills (*Buceros bicornis*)⁹ and in some *Lophoceros* and *Tockus* hornbills.^{7,8,10} It is also reported to exist in the southern ground hornbill

(*Bucorvus leadbeateri*),¹¹ though taxonomically they are from a different family (Bucorvidae), and differ in some nesting behaviours such as not sealing up their nest cavities and having helpers to raise their chicks.^{12,13} A list of hornbill species known to develop these air sacs is found in Table 1.

The development of this air sac system is also not well-described, though it is known to remain for longer periods in larger species, probably related to longer nestling periods.⁹ Air sacs develop within a day of hatch in *Lophoceros* and *Tockus* chicks, disappearing from about Day 13 when the chick develops feathers on its back.¹⁰ A study focusing on the development of this feature in wild Monteiro's hornbill (*Tockus monteiri*) chicks found that air sac development was related to age and mass of the nestlings. In this species, the air sacs decreased in size from Day 14 post-hatch, until their disappearance at Day 20, also coinciding with feather growth.⁸

Advanced and specific studies of this unique organ are required to ascertain its functions. However, this can be

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challenging as most hornbill species nest in high tree hollows and can aggressively defend their nests and young. Anatomical analysis of this feature would also require death of the chick. Specimens kept under human care may be able to help supply this data. This paper describes the presence and development of dorsal subcutaneous air sacs in the Von der Decken's hornbill (*Tockus deckeni*), using observations from a clutch of hand-raised chicks at the Jurong Bird Park (JBP) in Singapore.

Air sac development of *Tockus deckeni* chicks at Jurong Bird Park

Data was collected between October and November 2019 at JBP. Five Von der Decken's hornbill (*Tockus deckeni*) eggs were discovered in a nest box after the parent birds had been moved to another aviary, and were sent to the park's dedicated hand-rearing facility, the Breeding and Research Centre (BRC) for artificial incubation and hand-rearing.

Eggs were found to be in late stages of development upon collection. All were placed in Grumbach[®] incubators (ProCon automatic systems GmbH & Co. KG, Germany) at 37.2°C and 55% humidity, which are settings used to incubate chicken eggs. Incubator turning mechanisms were set at 24 turns a day (once every hour), for 10 min at each interval.

Eggs were checked twice daily for development. When large expansions in the air cell and/or internal pipping were observed, the egg was moved to a hatcher set at 75% humidity to complete the hatching process. The time between the first and last egg hatching was 13 days, with no more than 5 days between hatches.

Brinsea[®] TLC brooders (Brinsea Products Inc.) were used for chick housing. In the brooder, each chick was placed in a small bowl, lined with a multipurpose non-slip mat on top of absorbent paper towels. Larger containers were used as the chick grew, until it started walking and was given the entire brooder.

The initial temperature of the brooder was set at 37°C, and gradually lowered as the chicks feathered, or showed any signs of overheating or being cold, reaching 28°C by the time the chicks were fully feathered at about 30 days of age. Humidity was maintained above 65% for the first 5 days post-hatching, then gradually lowered to approximately 50%. All chicks were housed in pairs, except for the oldest, as it was considerably larger and heavier by the time the next chick hatched 5 days after.

All chicks were fed a combination of newborn mice (*Mus musculus*), soaked softbill pellets and papaya until 15 days of age, and gradually transitioned to a diet containing minced beef and other softbill foods (Table 2). Chicks were also supplemented with Nekton-MSA (1 g per kg body weight daily). Food items were moistened with water and fed using tweezers. Adult diets (invertebrates, softbill pellets, Uni Patee and diced fruit) were placed in a shallow plate at the stage when chicks started walking and exploring their brooder. Chicks were weighed daily, and air sacs examined and scored (Table 3). Air sacs were scored on

Table 1. List of hornbills (Bucerotidae, Bucorvidae) known to develop dorsal air sacs as chicks.⁷⁻¹⁰.

Scientific name	Common name
<i>Buceros bicornis</i>	Great hornbill
<i>Buceros rhinoceros</i>	Rhinoceros hornbill
<i>Bucorvus leadbeateri</i>	Southern ground hornbill
<i>Lophoceros alboterminatus</i>	Crowned hornbill
<i>Lophoceros bradfieldi</i>	Bradfield's hornbill
<i>Lophoceros nasutus</i>	African grey hornbill
<i>Rhyticeros undulatus</i>	Wreathed hornbill
<i>Tockus erythrorhynchus</i>	Northern red-billed hornbill
<i>Tockus flavirostris</i>	Eastern yellow-billed hornbill
<i>Tockus monteiri</i>	Monteiro's hornbill

sight, using a scale from 0 to 5, adapted from the study by Downs et al. on *T. monteiri*.⁸

All five chicks did not have any air sacs present on them at hatching (Figure 1) but developed them within 24 h. These air sacs appeared over their shoulders as small, separate air sacs by Day 2 (Figure 2). The two air sacs then join to form one large sac by Day 4 (Figure 3), continuously growing to cover most of the dorsal surface of the chick by Day 7 (Figure 4).

The air sacs stayed at this stage of development until Day 10, when the chicks started significant pin feather growth (Figure 5). At this age, the air sacs start receding, making it difficult to score them as they were not always inflated (Figure 6). They completely disappeared by Day 16, except for loose skin in some chicks (Figure 7). The chick has considerable feather growth at this age. Table 4 provides a more detailed summary of the air sac development in the five chicks.

Discussion

Prozesky⁷ and Kemp¹⁰ observed that air sacs in wild *Lophoceros* and *Tockus* chicks they studied inflate when the birds were handled or prodded, possibly promoting the hypothesis that these structures provide pneumatic protection. However, similar to the study by Downs et al.,⁸ our observations disagree with this, as the air sacs were found to be extremely soft and malleable to touch and would not provide adequate cushioning. They also did not inflate when the chicks were handled or prodded. Furthermore, they were not consistently inflated throughout the day and did not last the entire nestling period, disappearing or mostly deflated by the second week of age (from Day 10). The oldest chick that was reared alone also had the same air sac development and receding as the younger siblings kept in a group. The growth of air sacs is therefore not stimulated by congeners but rather is an adaptation every *Tockus* chick may have.

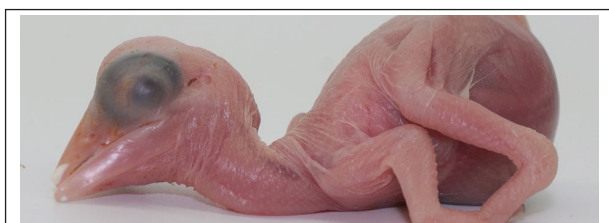
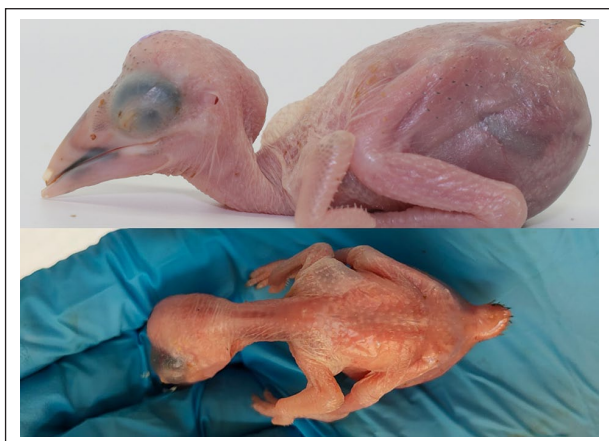
Wild chicks were observed inflating or deflating these air sacs according to changes in air temperature.⁹ However, in our captive setting, the use of brooders to regulate heat could mean the air sacs were less necessary for heat regulation and may have started receding earlier. Brooder temperatures were also adjusted according to the bird's feather

Table 2. Hand-feeding diet for *Tockus deckeni* chicks at Jurong Bird Park.

Age (in days)	Intake (% of body weight BW in grams)	Diet	Frequency (between 0600 to 1800h)
0–14	15%–20% BW/feed	60% Pinkies 20% Wisbroek Softbill Diet Large (soaked) 20% Papaya	Every 2 h
15 onwards	30% BW/day	40% Wisbroek Softbill Diet Large (soaked) 30% Minced beef 10% Papaya 10% Egg food 10% Versele-Laga Orlux Uni Patee Premium Universal Softbillfood I. All items can be mashed together and formed into small balls for hand-feeding Introduce live invertebrates (mealworms, crickets)	Every 3–4 h

Table 3. Scoring system for air sac development in *Tockus deckeni* chicks at Jurong Bird Park, adapted from Downs et al.⁸.

Score	Description
0	No air sac present.
1	Two air sacs on the shoulders, separated at the spine.
2	Two air sacs connect to form one large sac, on upper-half of back.
3	Air sac covers entire back.
4	Air sac covers back, flanks, neck and sides of chest.
5	Air sac not present; disappeared.

**Figure 1.** Lateral view of a newly-hatched Von der Decken's hornbill chick, day 0 (score 0). There is no air sac present.**Figure 2.** Lateral and dorsal views of a Von der Decken's hornbill chick, day 2 (score 1). There are two distinct pale, translucent air sacs over the shoulders, separated by the spine.**Figure 3.** Lateral and dorsal views of a Von der Decken's hornbill chick, day 4 (score 2). The two pale and translucent air sacs have joined to form one large sac on the upper-half of the chick's back.**Figure 4.** Lateral and dorsal views of a Von der Decken's hornbill chick, day 6 (score 3). More than half the back is covered by a pale and translucent air sac.

growth and behaviours (i.e. if they showed any signs of overheating or being cold, such as panting and shivering). It was sometimes difficult to score the air sacs from Day 8, as some were deflated for most of the day.



Figure 5. Lateral and dorsal views of a Von der Decken's hornbill chick, day 8 (score 4). The entire back is covered by a pale and translucent air sac, almost extending to the tail, and extending to the sides of the chest.

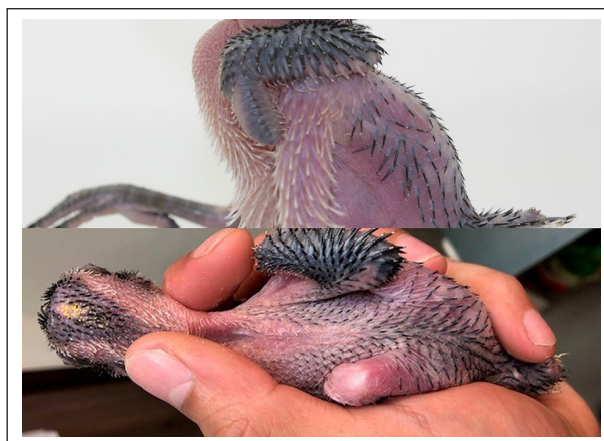


Figure 7. Lateral and dorsal views of a Von der Decken's hornbill chick, day 15 (score 5). The air sac has receded. Some loose skin is observed.



Figure 6. Lateral and dorsal views of a Von der Decken's hornbill chick, day 10 to 13 (score 4). The air sac is not always inflated, and shows signs of receding.

Table 4. Development of air sacs in hand-reared *Tockus deckeni* chicks.

Chick ID	Score				
	1	2	3	4	5
A	Day 1	Day 2	Day 3	Day 5	Day 14
B	Day 1	Day 2	Day 4	Day 6	Day 16
C	Day 1	Day 2	Day 4	Day 7	Day 16
D	Day 1	Day 3	Day 5	Day 7	Day 15
E	Day 1	Day 2	Day 4	Day 6	Day 14

Refer to Table 2 for system used to score air sac development.

The air sac system is known to remain for longer periods in larger species, probably related to longer nestling periods,⁹ and we found that this may also hold true for birds within the same genus. Wild Monteiro's hornbill (*T. deckenii*) chicks lose their air sacs by Day 20⁸; in comparison, the Von der Decken's hornbill chicks in this study lost theirs by Day 16.

The former weigh 269 to 423 g, while the latter is almost half the size at 120 to 212 g.^{14,15} If the relationship between air sac development and insulation holds true, it would make sense that they recede slower in larger species, as these birds take a longer time to develop pin feathers and other thermoregulatory mechanisms.

The family Bucerotidae consists of 62 known species across 16 genera, and more research needs to be conducted to see if the presence of air sacs occurs in other species, besides those already known. Further research is also required to determine the functions of these features. Studying them on wild hornbills is difficult, given that most species are elusive, live in dense forests, nest in high tree hollows and can be defensive over their nests and chicks. Zoological institutions and other captive facilities could be a useful resource in providing the necessary data to fill in this knowledge gap, as this data is much easier to gather using captive-bred specimens.

Acknowledgements

The author thanks Ellen Tay and Nurulhuda Hassan from the BRC for their help in data collection, and Dr Francis Cabana for important suggestions provided during early versions of this manuscript.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship and/or publication of this article.

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