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MORPHOLOGY OF THE LUNGS AND AIR SACS SYSTEM IN ROSY-FACED PARROTS (*AGAPORNIS ROSEICOLLIS*)

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ABSTRACT
The aim of this study is to morphologically describe the lungs and air sac system in Rosy-faced parrots (*Agapornis roseicollis*) and provide useful data for future veterinary care and treatment of respiratory system disease in these pets. The research was conducted on five birds. In order to obtain the casts of the lungs and air sacs, we applied the corrosion cast technique, where we used the 26% solution of Vinylite mass. The research showed that the basic anatomy of the lungs and air sacs in these parrots was very similar to that in other birds, but there is some specific characteristic regarding onto the arrangement and connection between the air sacs. In Rosy-faced parrots we identified a nine air sacs, the one upaired, *saccus clavicularis* and paired *saccus cervicalis, thoracicus cranialis, thoracicus caudalis* and *abdominalis*. Also, we recorded that clavicular and cranial thoracic air sacs establish a connection through the diverticula sternalia, what can be common to birds from Psittaciformes order.

KEYWORDS: Rosy-faced lovebirds, parrots, air sac, anatomy.

INTRODUCTION
The Rosy-faced (*Agapornis roseicollis*), also known as the Rosy-collared or Peach-faced lovebirds, are colourful, small in size, parrots from *Psittaciformes* order. These birds originated from south-west Africa, where they inhabit a dry, woodland, semi-desert and mountainous areas situated above 1600m of altitude.[1,2] Due to their small size, beautiful colour of the feathers, easy maintenance and breeding, these parrots are often kept in captivity as pets. During the mid-1980s some of these birds escaped from the captivity and established healthy, breeding population.[1] in the area of Phoenix and Arizona (USA). Although they are popular as pets, the anatomy of Rosy-faced lovebirds still is very poorly researched. Recently there have been a couple of reports from different veterinary clinics regarding the treatment of respiratory and other diseases in these birds.[3-5] The respiratory system diseases today are very common health problem in birds kept in captivity. It is well known that the anatomy of the bird's respiratory system is one of the most complex and, in terms of functionality, the most efficient among the vertebrates.[6,7] The complex anatomical arrangement of this system is a direct reflection of the evolutionary adaptation of the birds to the flight and different habitats. The birds possess system of the air sacs and parabronchi connected to the lungs, and those structures represent them morphologically unique in the animal kingdom.[8-13] In the last four and a half centuries, a lot of research has been conducted with the aim to morphologically describe and functionally explain the air-sacs system in different species of the birds.[14-25] The results of these studies confirm that are many differences among the birds' species in the number, size and shape of air sacs and their diverticula. However, we did not find in available literature any information about the anatomy of respiratory system in Rosy-faced parrots. In that regard, the main aim of this study was to morphologically describe the lower part of the respiratory system of these parrots, particularly the lungs and air sac system, and by doing so, provide useful data for future veterinary care and treatment of respiratory system disease in these pets.

MATERIALS AND METHODS
The research was conducted on five Rosy-faced lovebirds, two males and three females. All birds were

aged from three to six years and did not have any health issues. The birds were kept in a private household as pets, where they died from freezing after heating system collapsed. The owner donated the birds to the University of Sarajevo, the Veterinary faculty, the Department of Anatomy and Histology with Embryology, where we performed detailed morphological study of the lower part of their respiratory system, particularly the lungs and the air sacs. For this examination, we applied the corrosion cast technique.[26] The casts of the lower part of the respiratory system were prepared by using the 26% solution of Vinylite mass dissolved in acetone p.a. The prepared mass was additionally coloured in yellow (BIODUR® Colour Paste Corn Yellow AC 53) for better visualisation. The Vinylite mass was injected into the lumen of the trachea by plastic syringe with needle. During the injection, the pressure on abdominal wall was constantly monitored by manual palpation. When desired pressure was achieved, the injection of the Vinylite mass was stopped and trachea was enclosed by surgical forceps. The birds were emerged into the tap water for 24 hours so that the Vinylite mass would harden. Later, three birds (two female and one male) ware placed into the device for soft tissue maceration of biological specimens (Schaerer, Weber-Bern), and the other were dissected. Dissected specimens were used for *in situ* morphological investigation and description of the lungs, air sacs and their diverticula. All dissected specimens were later permanently preserved in 3% formalin. The other birds were macerated and these specimens were later used for detail visualisation of the lungs and air sac casts. The process of maceration lasted 21 days. After that period, the specimens were washed in tap water and left to dry for 24 hours. At the end of this process, we got the full cast of the lungs and air sacs with preserved skeleton. For better visualisation of the casted structures we removed some of the bones. On these specimens we determined the position, shape and size of the air sacs and their diverticula. For proper Latin terminology we used the *Nomina Anatomica Avium*.[11]

RESULTS

The lungs of Rosy-faced lovebirds are small and situated in the dorsal and lateral part of the thoracic cavity. The five deep costal grows can be identified on their costal and vertebral surface (Figure 1). The lungs cover the heart from above and caudally reach the cranial margin of the kidneys. The Vinilyte casts show that Rosy-faced parrots have nine air sacs and there is no difference between male and female birds. The one, *saccus clavicularis* is unpaired, while the other, *saccus cervicalis, saccus thoracicus cranialis, saccus thoracicus caudalis* and *saccus abdominalis* are paired (Figure 2, 3).

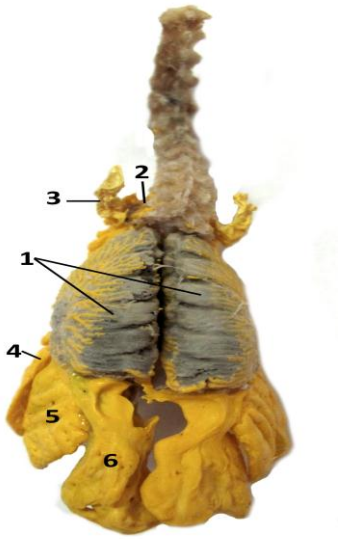

Figure 1. Dorsal view on the lungs and air sacs in Rosy-faced lovebirds corroded and dissected *in situ*. There are visible: 1. lungs, 2. cervical air sacs, 3. diverticulum suprahumerale of the clavicular air sac, 4. cranial thoracic air sacs, 5. caudal thoracic air sacs and 6. abdominal air sacs.

Saccus clavicularis

The clavicular air sac occupies the cranial and central part of the thoracic cavity. Its main chamber lies between the pectoral girdle, sternum and the base of the heart (Figure 2,). From its main chamber the six diverticula, two intra-thoracic and four extra-thoracic separate (Figure 1, 2). The intra-thoracic are *diverticula cardiaca* and *sternalia*. The cardiac diverticula cover the base of the heart and atrial wall. The sternal diverticula emerge from caudoventral part of the clavicular air sack. From its lateral side emerges one tubus-like extension through which this deverticula connects with the cranial thoracic air sac (Figure 2, 3). The four extra-thoracic diverticula of clavicular air sac are: *diverticulum subpectorale, suprahumerale, axillare* and *subscapulare* (Figure 2, 3). The subpectoral diverticulum emerges from craniolateral side of the clavicular air sac. These diverticula have a triangular shape and laterally they are pierced by the axillar artery and vein. The left and right subpectoral diverticula are connected by one large extension who is

situated above the trachea (Figure 4). Small axillary diverticula emerge laterally from the previous. It has a leaf-like shape and occupies the ventrolateral side of the shoulder joint. The suprahumeral diverticula are much larger and emerge above axillary diverticula (Figure 1, 2, 3). They cover the head of the humerus. The subscapular diverticula is the smallest of all and occupy the spaces between the first two thoracic vertebra (Figure 3).

Saccus cervicalis

The cervical air sacs are small, paired and situated between the subpectoral diverticula of the clavicular air sac (Figure 4). These sacs gives two diverticula (*diverticulum vertebralia* and *intermuscularia*) that follow the vertebral column from the first thoracic to last five or six cervical vertebrae. The vertebral diverticula enter into the transversal and vertebral canal while the intermuscular diverticula penetrate the muscles in the caudal neck region (Figure 2, 3).

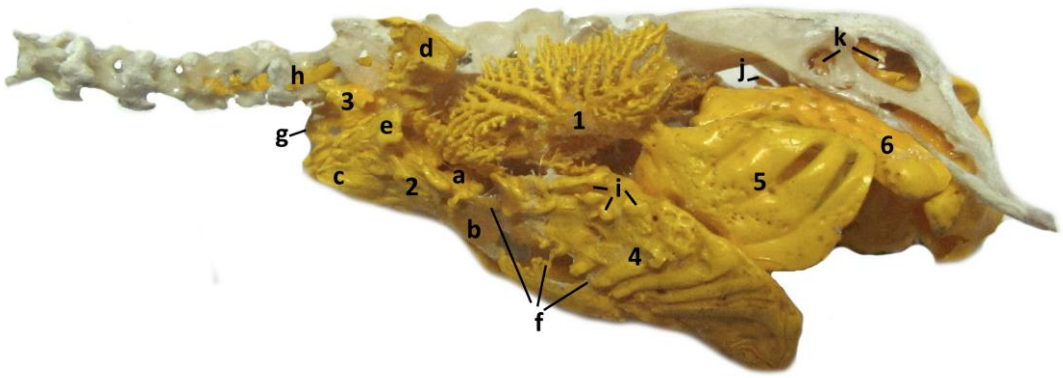

Figure 2. Lateral, *in situ* view of corroded and macerated bronchi and air sacs system, where can be identified: 1. lungs, 2. clavicular air sacs with its diverticula cardiaca (a), sternalia (b), subpectorale (c), suprahumerale (d) and axillare (e), 3. cervical air sac with its diverticulum intramusculare (g) and vertebrale (h), 4. cranial thoracic air sac with its connections with clavicular air sac (f) and small dorsal diverticula (i), 5. caudal thoracic air sac, 6. abdominal air sac with its divertiucula perirenalia (j) and femoralia (k).

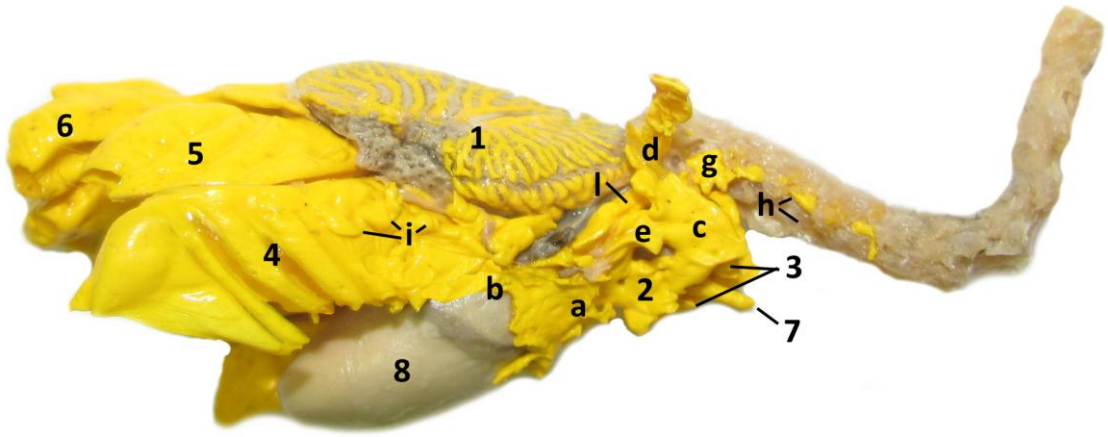

Figure 3. Lateral, *in situ* view on corroded and dissected specimen where are visible: 1. lungs, 2. clavicular air sac with its diverticula cardiaca (a), sternalia (b), subpectorale (c), suprahumerale (d) and axillare (e), subscapulare (l), 3. cervical air sac with its diverticulum intramusculare (g) and vertebrale (h), 4. cranial thoracic air sac with its small dorsal diverticula (i), 5. caudal thoracic air sac, 6. abdominal air sac, 7 trachea, 8. heart.

Saccus thoracicus cranialis

The cranial thoracic air sacs are large, oval and situated on the sternal parts of the ribs. Their dorsal margin reaches the point where vertebral and sternal extremity of the ribs joins. Only small part of these sacs protrudes caudally from the rib cage. From their lateral and cranial side emerge small diverticula who aerates the vertebral part of the ribs. Similar diverticula exit from the ventral margin of these sacs and aerate the first six sternal ribs (Figure 2, 3). The cranial thoracic air sacs connect with sternal diverticula of the clavicular air sac as it described previously (Figure 2, 3).

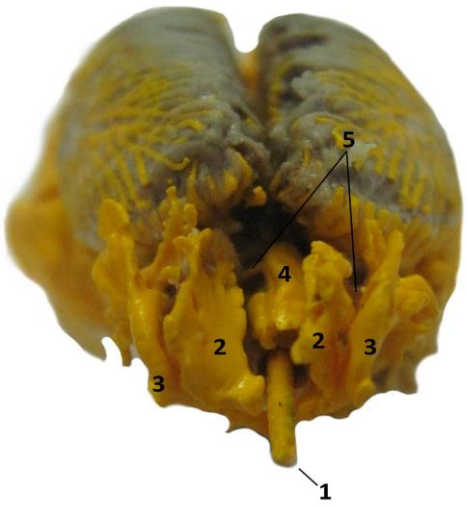

Figure 4. Cranial view on corroded and *in situ* dissected specimen where are visible: 1. trachea, 2. cervical air sacs, 3. diverticulum subpectorale of clavicular air sac and theirs connection (4).

Saccus thoracicus caudalis

The caudal thoracic air sacs are smaller than the previous and they are situated on the vertebral parts of the ribs (Figure 2). The small, caudodorsal part of these sacs protrudes caudally from the last pair of the ribs. These air sacs do not give any diverticula or aerate the bones.

Saccus abdominalis

The abdominal air sacs are the largest and most voluminous. They occupy the dorsolateral side of coelomic cavity, extending from the caudal margin of the lungs to the cloaca (Figure 2). The right abdominal sac is slightly larger than the left. In the middle part, the left abdominal sac is constricted (Figure 1). These sacs give small perirenal and femoral diverticula (Figure 2). The perirenal diverticula emerge from their dorsolateral side and aerate the synsacrum and osilium. The femoral diverticula separate in the level of the hip joint and penetrate the acetabulum, os ilium and ishi.

DISCUSSION

The anatomy of the lower part of the respiratory system is quite variable among the avian species and these variations come as results of bird's evolutionary adaptation to the flight and different habitats.[7] The most intensive research on the lung and air sack system has been conducted on domestic birds. In today's official literature it has been stated that domestic Fowls have eight air sacs, an unpaired cervical and clavicular sack and paired cranial thoracic, caudal thoracic and abdominal air sacs.[10-13] However, in some reports it has been noted that there are nine air sacs present in these birds.[6,16,23,25] These differences appear as results of a different description of the cervical air sac. It is well known that the cervical air sac in domestic Fowl are paired during the embryonic development, while later, after the hatching they fuse and form one main chamber from which two thin diverticula separate and goes bilaterally along the cervical vertebra.[10,11] In some research these diverticula have been described as paired cervical air sacs, which leads to a different interpretation of the number of air sacs.[6,16,23,25] The similar anatomical arrangement of the air sacs also has been found in some wild birds such as: Mallard and Golden Peking Duck,[18,22] Long-legged Buzzard,[20] Bulbul,[25] some birds species from *Procellariiformes* order.[17] *Strigidae* and *Ardeidae* family,[15,16] while in some species it has been recorded the fusion of the cervical and clavicular air sacs, and that leads to their lesser number. The fusion of the air sacs have been found in Japanese Quails,[21] Turkey,[24] Goose,[19] and Pigeon.[9] However, in present literature we did not find any data about the anatomy of the respiratory system in Rosy-faced lovebirds. Our research showed that the lungs and the air sacs system in these parrots are very similar to those in domestic Fowls, but there are some important differences among these two species. In Rosy-faced lovebirds, the cervical air sacs were paired, but they had the same diverticula as in Fowls. However, these diverticula do not extend cranially to the axis as in Fowl. They extend only from the first two thoracics to the last five or six cervical vertebra. The clavicular air sac in our birds was unpaired as in Fowls, but there are some significant differences among the species. In our birds, the clavicular air sac was connected through their diverticula sternalia with cranial thoracic air sacs. The connections between these sacs so far have been recorded in a Common grackle, Cardinals, Rufous-sided Towbees, Song Sparrow and some individual Old World song birds,[14] but not in Fowls or other domestic birds.[10-13] Also, in Rosy-faced lovebirds we identified and connection between left and right subpectoral diverticula of clavicular air sac. We did not find any data abut this connection in other birds. In domestic Fowls and the bulbul, it has been found that the cranial thoracis air sacs are smaller than the caudal and both of them do not possess any diverticula.[9,10,12, 19] Our research partially agrees with this statement. We found that cranial thoracic air sacs in Rosy-faced lovebirds

were larger then caudal and from their ventral margin and cranio lateral side emerges small diverticula who aerate the ribs. Similar observations have been recorded in Long-legged Buzzard,[20] Golden Peking[18] and Mallard Duck.[22] Additionally, in Long-legged Buzzard two specific diverticula of the cranial thoracic sacs have been recorded, *diverticulum subcardiale and supracardiale*, but we did not find those in our birds.[22] The caudal thoracic air did not have any diverticula and that is in agreement with previuos research.[10-13] Also, as in many many other birds, we recorded that the abdominal air sacs were the largest and most voluminous. In domestic Fowls, the right abdominal sac is slightly larger than the left and our research coincides with these findings, with the addition that on the left sac we identified a small constriction in its middle part. [9,13] In conclusion, the present research showed that the Rosy-faced lovebirds have a specific anatomical arrangement and connection between the air sacs and additional research needs to be performed to see are these features generally common to the birds from *Psittaciformes* order.

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