

Gross Morphological Features of the Lung and Air Sac in the Japanese Quail

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ABSTRACT. This study was conducted to reveal the morphological characteristics of the lung and air sacs in *Coturnix coturnix japonica* (Japanese quails). Ten quails were allocated into two groups. Tracheas of 5 quails with neoprene latex and 5 quails with methylmetacrylate were injected to fill the trachea and air sacs. Latex embalmed animals were stored in 10% formaldehyde solution for two months. Animals given methylmetacrylate were maserated in 30% potassium hydroxide at 40°C for two days. Lungs were located in the dorsal part of the thorax and very close to the thoracic vertebrae and ribs. Shorter than the dorsal border, the ventral border lied between the 3rd and 6th ribs. Cervical, clavicular, cranial thoracic, caudal thoracic and abdominal sacs were identified. These sacs had connection with the 3rd, 4th and 5th lateroventral and 4th mediolateral bronchi. *Saccus cervicalis* was located on the left and right portions of the *vertebrae cervicales et thoracicae* with a pronounced communication ventromedially. However, the cervical sac aeration of only all cervical vertebrae was present in this study. Humerus was a non-aerated bone. Pneumatic foramen was absent and did not aerate the sternum. Cranial thoracic sac connected to the 1st, 2nd and 4th medioventral bronchi and gave no diverticulum for aeration. Cranial thoracic sac received air through the 4th medioventral and the 1st and 2nd lateroventral bronchi. Left and right abdominal air sacs paramedially produced *diverticulum femorale*, but this diverticulum did not enter the femur.

KEY WORDS: air sacs, Japanese quail, lung, morphology.

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Avian respiratory system comprises unique structures among the vertebrates, with relatively small lungs whose volumes are not changeable during breathing. It, hence, possesses nine air sacs which participate in the ventilation of the lungs but do not interfere directly with gas exchange [2, 19].

The primary bronchi, bifurcation of the trachea at the level of the syrinx in general, continue their travel through the entire length, exiting at the caudal border, of the lungs [2, 16]. From these primary bronchi, originate the secondary bronchi at different location and with different number, covering the medioventral and mediodorsal surfaces of the lungs. These bronchi do not participate in gas exchange; however, they conduct the air ways to the air sacs [2, 3, 11, 19].

Morphology of the lungs and air sacs in different avian species has fairly been studied, and their features have been well documented [1, 11, 14, 18, 20]. However, research on this issue in Japanese quail, on the other hand, is thought to be limited. Thus, this study was conducted to reveal the morphological characteristics of the lungs and air sacs of the Japanese quail (*Coturnix coturnix japonica*).

MATERIALS AND METHODS

Animal welfare and directory of ethical committee of Ankara University were considered during the experimental procedure. Tracheas of the Japanese quails obtained from the Faculty of Agriculture, Ankara University, Turkey, were cannulated with plastic tube through which colored-Neoprene latex (5 quails) or takilon (methylmethacrylate) (5

quails) was injected to fill the lungs and air sacs, under deep anesthesia with ketamine hydrochloride (Parke-Davis) and xylazine hydrochloride (Bayer) combination (60 mg/kg and 6 mg/kg, respectively). The animals were kept under deep anesthesia to allow the cast material get through the bronchi and air sacs. Then, latex embalmed species were put in 10% formaldehyde solution for polymerization for two months. Takilon given materials were maserated in 30% potassium hydroxide solution at 40°C for 2 days. Finally, they were cleaned and photographed by means of a stereomicroscope (Olympus Optical Co., Ltd.).

Nomina Anatomica Avium (3) was used for the nomenclature.

RESULTS

The sponge-like lungs of the Japanese quail (Figs. 1 and 2A/f, B/f, C/f and D/f) were bright red in color, had no lobe, and were of the same size and shape. They were located in the dorsal part of the thorax and very close to the thoracic vertebrae and ribs. Their sharp cranial extremities extended as far as the second ribs. Shorter than the dorsal border, the ventral border lied between the 3rd and 6th ribs.

The lungs had three surfaces. The convex costal surface was very close to the ribs and intercostal muscles, possessing the impressions of the ribs. The medial surface was convex, facing with its counterpart. The hilus of the lungs was located on the cranioventral end of this surface. They had also concave ventral surfaces in shape.

The trachea was divided into two parts after the syrinx; the right and left primary bronchi. The extrapulmonary part

of the primary bronchi joined the lungs at the hilus (Fig. 1a), becoming the intrapulmonary part of the primary bronchi (Fig. 1b). As far as the gross examination was concerned, these primary bronchi possessed no cartilaginous rings, and progressed until the caudal border of the lung by decreasing its diameter. During this course, it projected four types of secondary bronchi. These were like the continuation of it, as far as the morphology was concerned.

There were four medioventral secondary bronchi which arose from the dorsomedial wall of the primary bronchi (Fig. 1c), supplying the medial and ventral regions of the lung. The mediodorsal secondary bronchi left the primary bronchi from the dorsal wall traveled dorsally, supplying the medial and dorsal regions. Similarly, origins of the lateroventral and laterodorsal secondary bronchi were opposite to those of the medioventral and mediodorsal secondary bronchi, respectively (Fig. 1d). They had connection with related regions of the lungs. All the secondary bronchi gave the tertiary bronchi and parabronchus (Fig. 1e). They were much smaller in diameter as compared to the primary bronchi.

The air sacs related to the lungs in Japanese quail were the cervical sac, *saccus cervicalis*, the clavicular sac, *saccus clavicularis*, the cranial thoracic sac, *saccus thoracicus cranialis*, the caudal thoracic sac, *saccus thoracicus caudalis*, and the abdominal sac, *saccus abdominalis*.

The cervical sac (Fig. 2A/a, B/a, C/a and D/a): The cervical sac was present in front of the cranial border of the lungs and among the clavicular sac, trachea, esophagus, and neck muscles. The right and left cervical sacs, bilaterally located at the right and left sides of the *vertebrae cervicales et thoracicae*, made contact ventromedially with each other, but had no connection. The caudal border of the sac was limited by the 2nd rib.

The cervical sac showed no intermuscular and subcutaneous diverticula. However, *diverticula vertebralia* of the sac, being small and thin projections, were in connection with their counterparts through the transverse and intervertebral foramina of the cervical vertebrae. This fusion extended up to the 1st cervical vertebra. These air sacs were communicated with the lungs via the 1st medioventral bronchi (Fig. 2B/I). The cervical sac aerated all the cervical vertebrae.

The clavicular sac (Fig. 2A/b, B/b, C/b and D/b): The clavicular sac was a single air sac formed by the partial fusion of the bilaterally located parts. These parts resembled "V" shape, were ventrally connected under the trachea and attachment of the wings to the body, and occupied the cranial thoracic aperture completely. The sac was located cranial to the heart and cranioventral to the lungs, and was limited by the thoracic girdle and sternum. Trachea and esophagus lied dorsal to the sac separating it from the cervical sac. It had 2 separate connections with the lungs; the caudolateral parts through the 1st and 2nd, and the caudomedial parts with the 3rd medioventral bronchi (Fig. 2B/II and D/II).

The clavicular sac possessed all the intra- and extrathoracic diverticula. Intrathoracally located cardiac diverticu-

lum (Fig. 2A/b1, B/b1, C/b1 and D/b1), in rectangular shape, was cranioventral to the base of the heart. The sternal diverticulum (Fig. 2A/b2, B/b2, C/b2 and D/b2) extended along the sternum; on that it started cranial to the sternum, and ended by lying throughout the caudoventral border of the sternum. Since the pneumatic foramen was absent, this diverticulum did not aerate the sternum.

The diverticula located extrathoracally were scattered by the cranial thoracic apertura. The subscapular diverticulum was present between the scapula and cervical sac (Fig. 2A/b3 and B/b3). It was not fully developed and close to the clavicular sac. The axillar diverticulum was found ventral to the head of the humerus in chick-pea like appearance, beneath the shoulder muscles (Fig. 2A/b4, B/b4, C/b3 and D/b3). This diverticulum was composed of highly developed humeral component. Another diverticulum lying extrathoracally was the long subpectoral diverticulum (Fig. 2A/b5, B/b5, C/b4 and D/b4) which was located caudal to the axillar and humeral sacs, caudodorsal to the sternal diverticulum and cranioventral to the lungs, and beneath the pectoral muscles. It had a trace of the 1st rib on it. Finally, the last extrathoracally located one, suprahumeral diverticulum (Fig. 2C/b5 and D/b5) was dorso-caudal to the axillar diverticulum, enclosing the dorsal part of the shoulder, and this diverticula did not aerate the humerus.

The cranial thoracic sac (Fig. 2A/c, B/c, C/c and D/c): Not perfectly symmetrically located, the cranial thoracic sacs were nearly rectangular in shape. The sac was limited laterally by the 4th, 5th and 6th ribs, and by the lateral and intermedial trabecula of the sternum. It covered the ventromedial surface of the lungs. Medial border of the sac was in relation with the heart, liver and esophagus. The sac connected to the 1st, 2nd and 4th medioventral bronchi (Fig. 2B/III and D/III), giving no diverticulum for aeration.

The caudal thoracic sac (Fig. 2A/d, B/d, C/d and D/d): The caudal thoracic sac showed a triangle-shape symmetrically located caudoventral to the lungs. Cranioventral border of the sac was also in relation with the last two ribs. Its extension was roughly similar to the cranial thoracic one. Since medial surface of the sac was entirely covered by the abdominal sac, it displayed no relation with the viscera, especially caudally located ones. As was the case in the cranial thoracic sac, this sac had no diverticulum to aerate any bones. The sac received air through the 4th medioventral and 1st and 2nd lateroventral bronchi (Fig. 2B/IV).

The abdominal sac (Fig. 2A/e, B/e, C/e and D/e): The abdominal sac was significantly larger as compared to the others and possessed asymmetrically located two parts in the abdomen. Its extension was from the caudodorsal border of the lungs through the cloacae. The right abdominal sac was roughly 13.3 mm longer than the left one. On the other hand, the left abdominal sac was wider.

The right abdominal sac had the impression of the spleen on its craniomedial surface and that of the intestine on the caudomedial surface. It was limited laterally by the abdominal and partly pelvic walls. The sac; hence, covered entirely the ventral surface of the kidney and the roof of the

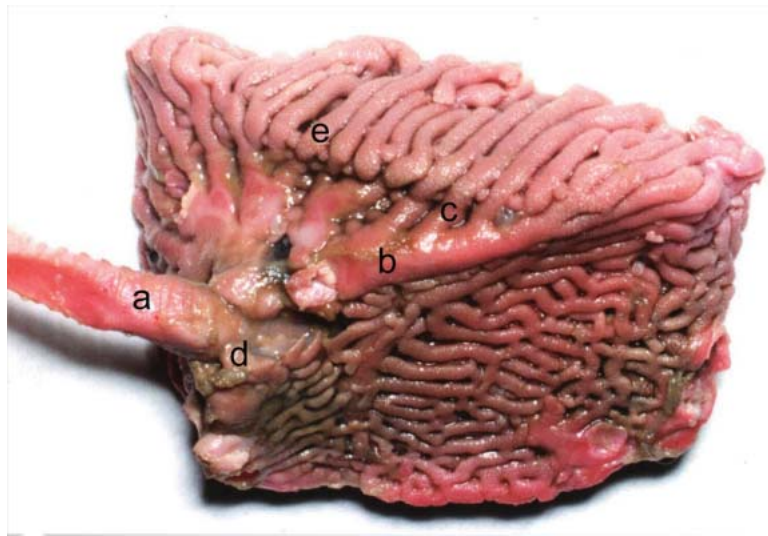


Fig. 1. Ventromedial view of the plastic cast of the left lung of the Japanese quail. a-Extrapulmonary part of the primary bronchi, b- Intrapulmonary part of the primary bronchi, c- Medioventral secondary bronchi, d- Mediiodorsal secondary bronchi, e- Parabronchus.

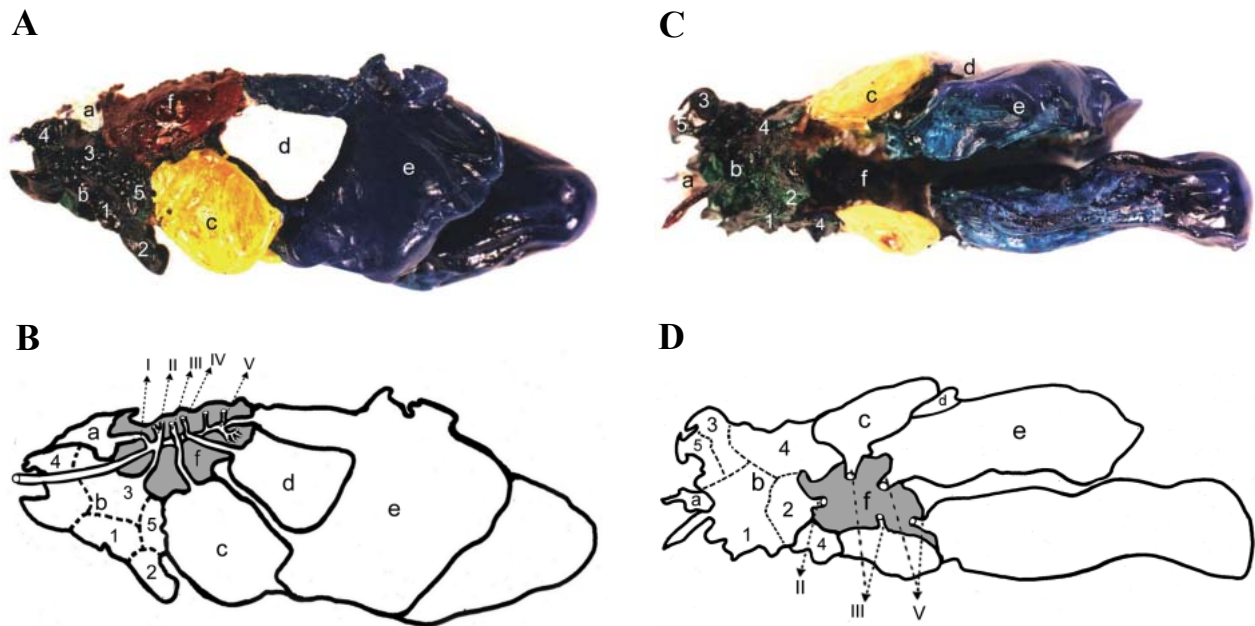


Fig. 2. Air sacs in Japanese quails "Corrosion cast". A) Left lateral view. a- Cervical sac, b- Clavicular sac, b1- Cardiac diverticulum, b2- Sternal diverticulum, b3- Subscapular diverticulum, b4- Axillar diverticulum, b5- Subpectoral diverticulum, c- Cranial thoracic sac, d- Caudal thoracic sac, e- Abdominal sac, f- Lung. B) Schematic drawing of left lateral view. a- Cervical sac, b- Clavicular sac, b1- Cardiac diverticulum, b2- Sternal diverticulum, b3- Subscapular diverticulum, b4- Axillar diverticulum, b5- Subpectoral diverticulum, c- Cranial thoracic sac, d- Caudal thoracic sac, e- Abdominal sac, f- Lung, I- 1st medioventral bronchi, II- 1st, 2nd and 3rd medioventral bronchi, III- 1st, 2nd and 4th medioventral bronchi, IV- 4th medioventral and 1st, 2nd lateroventral bronchi, V- 3rd, 4th and 5th lateroventral and 4th medioventral bronchi. C) Ventral view. a- Cervical sac, b- Clavicular sac, b1- Cardiac diverticulum, b2- Sternal diverticulum, b3- Axillar diverticulum, b4- Subpectoral diverticulum, b5- Subhumeral diverticulum, c- Cranial thoracic sac, d- Caudal thoracic sac, e- Abdominal sac, f- Lung. D) Schematic drawing of ventral view. a- Cervical sac, b- Clavicular sac, b1- Cardiac diverticulum, b2- Sternal diverticulum, b3- Axillar diverticulum, b4- Subpectoral diverticulum, b5- Subhumeral diverticulum, c- Cranial thoracic sac, d- Caudal thoracic sac, e- Abdominal sac, f- Lung, II- 1st, 2nd and 3rd medioventral bronchi, III- 1st, 2nd and 4th medioventral bronchi, V- 3rd, 4th and 5th lateroventral and 4th medioventral bronchi.

pelvis. Similarly, the left abdominal sac possessed impressions of some viscera; that of the gizzard ventromedially and that of the intestine caudally. Its dorsal border covered also the left kidney.

Both the right and left abdominal sacs gave paramedially a couple of diverticula, *diverticulum femoralia*, on their dorsal surface. This sac had no diverticulum for aeration also. This sac was connected with the lungs by the 3rd, 4th, and 5th lateroventral and 4th medioventral bronchi (Fig. 2B/V and D/V).

DISCUSSION

It was shown that quails had bright red and sponge-like lungs without lobes [7, 9]. In other avian species, such as hens, lungs are rectangular and flat [9, 10]. Lungs of penguin, a primitive bird, are triangular in shape, and their ventral end is blind [9].

Trachea was divided into two branches, right and left extrapulmoner primer bronchi. After the syrinx, it, intrapulmonerly, sent off secondary bronchus that had no cartilage rings after advancing the hilus [2, 9]. King *et al.* [9] and King [10] considered that parabronchi, termed as tertiary bronchi that anastomosed with each other, were constructed by the branches originated from secondary bronchi.

We showed on gross examination that air sacs had connection with the 3rd, 4th and 5th lateroventral and 4th mediolateral bronchi. The thoracic sac: 1st, 2nd, and 4th medioventral bronchi. The caudal thoracic sac: 1st and 2nd lateroventral bronchi. The abdominal sac: 3rd, 4th, and 5th lateroventral and 4th medioventral bronchi. However, Bacon [2] previously reported that primer bronchus extended to the caudal border of the lung and penetrated into the abdominal air sac. It had connection with lateroventral secondary bronchi or directly with primer intrapulmoner bronchi.

Generally, air sacs are examined as; *saccus cervicalis*, *saccus clavicularis*, *saccus thoracicus cranialis*, *saccus thoracicus caudalis* and *saccus abdominalis* [2, 6, 11, 18, 20]. *Saccus cervicalis* in Denizli rooster is dorsally located on the left and right portions of the *vertebrae cervicales et thoracicae* with a pronounced communication. However, this communication is seen ventromedially in the quails studied hereby.

The cervical sac aerates the vertebral column from the 3rd cervical to the 5th thoracic vertebrae inclusive and the first two vertebral ribs in chickens [13], however, no indication of aeration of vertebral ribs is present [20]. King [11] stated in *Gallus domesticus* that the extensions of the sac along the vertebral column, reached the aerated spaces of the cervical and thoracic vertebrae. However, the cervical sac aeration of only all cervical vertebrae was present in the quails of this study. This sac had no intervention on the aeration of the thoracic vertebrae.

As far as the findings of the clavicular air sac of this observation were concerned, they mostly agreed with those of Lucas *et al.* [14], and Ringdon *et al.* [18] that the inter-

clavicular air sacs were fused to form one sac. *Diverticulum humerale* aerated humerus in *Gallus domesticus* [11], Denizli rooster [21], White Pekin duck [15] and fowls [8], but not in the quails of this study. Therefore, this study indicated that humerus in the quail is a non-aerated bone.

King [12] stated in *Gallus domesticus* that the rostrum and the craniolateral process were quite fully aerated. Moreover, according to Akester [1], the sternum was pneumatic to a much greater extent in the pigeon than in the fowl, but in this study, the pneumatic foramen was determined to be absent and did not aerated the sternum. The cranial thoracic sac was connected through the *ostium thoracale craniale* with the third ventrobronchus of the appropriate site [17]. In this study, the sac connected to the 1st, 2nd and 4th medioventral bronchi and gave no diverticulum for aeration. The caudal thoracic sac was not found to be a kind of such sac as reported by Lucas *et al.* [14], but Das *et al.* [5] stated that two caudal thoracic sacs were distinctly separated by an oblique septum, however, it was an only one sac in the quails of this study. These sacs were reported to receive air through the laterobronchi of their own side [17], but our study showed seven bronchi of the sac received air through the 4th medioventral and the 1st and 2nd lateroventral bronchi.

The left abdominal sac in Denizli rooster was slightly larger than the right one [21]; however, in this study, the right sac was larger than the left one in the quails. In accordance with Taylor *et al.* [20] and Fitzgerald [7], the left and right abdominal air sacs paramedially produced *diverticulum femorale* which had no entry into the femur. According to Çalışlar [4], the diverticulum pneumatized the lumbar vertebrae, sacrum and coxae and, in ostriches, it penetrated into the femur through a large foramen in front of the trochanter major. The abdominal sacs (larger one) gave several diverticula and located at the milieu of *caput femoris* [18].

In conclusion, we hope that the data generated here may provide valuable contribution to the understanding of morphology of air sacs in Japanese quails. Furthermore, clinicians who are interested in diseases and surgery of quails may get some benefits from this study.

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REFERENCES

1. Akester, A.R. 1960. The comparative anatomy of the respiratory pathways in the domestic fowl (*Gallus domesticus*), pigeon (*Colomba livia*) and domestic duck (*Anas platyrhynchos*). *J. Anat.* **94**: 487–505.
2. Bacon, L.W. 1997. Avian Physiology Lecture Notes. Department of Poultry Science, The Ohio-State University.
3. Baumel, J.J., King, A.S., Breazile, J.E., Evans, H.E. and Vanden Berge, J.C. 1993. *Nomina Anatomica Avium*. Published by The Nuttall Ornithological Club. No: 23, Cambridge,

- Massachusetts.
4. Çalışlar, T. 1984. Anatomy of Domestic Animals II: Horse and Poultry Dissection, Istanbul University Press, Istanbul, Turkey.
 5. Das, L.N. and Mishra, D.B. 1965. Comparative anatomy of the domestic duck. *Ind. Vet. J.* **42**: 320–326.
 6. Doğer, S. and Erençin, Z. 1964. Comparative Anatomy of the Domestic Birds. Ankara University Press, Ankara, Turkey.
 7. Fitzgerald, T.C. 1970. The Coturnix Quail Anatomy and Histology. Iowa State University Press, Ames, Iowa.
 8. Hogg, D.A. 1984. The distribution of pneumatisation in the skeleton of the adult domestic fowl. *J. Anat.* **138**: 617–629.
 9. King, A.S. and McLelland, J. 1984. Birds; their structures and function. 2nd ed., Bailliere & Tindal, London.
 10. King, A.S. 1975. Aves respiratory system. pp. 1883–1918 *In*: The Anatomy of the Domestic Animals, 5th ed. (Getty, R. ed.), W. B. Saunders Company, Philadelphia.
 11. King, A.S. and Payne, D.C. 1962. The maximum capacities of the lungs and air sacs of *Gallus domesticus*. *J. Anat.* **96**: 495–503.
 12. King, A.S. 1957. The aerated bones of *Gallus domesticus*. *Acta Anat.* **31**: 220–230.
 13. King, A.S. and Kelly, D.F. 1956. The aerated bones of *Gallus domesticus*: the fifth thoracic vertebra and sternal ribs. *Br. Vet. J.* **112**: 279–283.
 14. Lucas, A.H., Keeran, R.J. and Coussens, C. 1959. Air sacs of chicken, turkey, duck and owl. *Anat. Rec.* **133**: 452.
 15. Mennega, A. and Calhoun, M.L. 1968. Morphology of the lower respiratory structures of the white Pekin duck. *Poult. Sci.* **47**: 266–280.
 16. McLelland, J. 1990. A Colour Atlas of Avian Anatomy. Wolfe Publishin Ltd, Aylesbury, England.
 17. Nickel, R., Schummer, A. and Seiferler, E. 1977. Anatomy of the Domestic Birds. Verlag Paul Parey, Berlin-Hamburg.
 18. Rigdon, R.H., Ferguson, T.M., Feldman, G.L. and Couch, J.R. 1958. Air sacs in the turkey. *Poult. Sci.* **37**: 53–60.
 19. Sturkie, P.D. 2000. Avian Physiology, 5th ed. Springer-Verlag, New York.
 20. Taylor, R.O., Bcone, M.A. and Barnett, B.D. 1962. Plastic infusion and casting of the avian air sacs. *Poult. Sci.* **41**: 1940–1943.
 21. Taşbaş, M., Hazıroğlu, R.M., Çakır, A. and Özer, M. 1994. Morphological investigations of the respiratoric system in Denizli Cocks. *Ank. Univ. Vet. Fak. Derg.* **41**: 154–168.