THE ROLE OF AIR SACS: ITS STRUCTURE, FUNCTION AND APPLICATIONS

Tamanna Agrawal*, Rajkumar Siyag, Praveen Kumar Gill, Sandeep Kumar, Ayushi Sharma
Department of Veterinary Anatomy
College of Veterinary and Animal Science, Bikaner
Rajasthan University of Veterinary and Animal Sciences, Bikaner (Rajasthan)
**Corresponding author e-mail: tamanamvsc@gmail.com*

ABSTRACT

The main function of respiratory system is to exchange of oxygen and carbon dioxide between tissue and lungs and lungs to environment respectively. In birds, the respiratory system is complex and are provided with paired and unpaired air sacs, a unique anatomical feature that act as bellows and help lungs (parabronchi) in gaseous exchange by holding air that enters into the sac (from trachea) before entering into the lungs. These sacs are highly avascular and hence do not help in gaseous exchange but provide unidirectional flow of air within the system. The gaseous volume of bird's lung is small but the total volume of respiratory system is twice to that of mammals (comparable sizes) due to the presence of air sac that are connected to lungs and bronchi.

Keywords: Air sacs, respiration, thorax, quail

I. INTRODUCTION

Air sacs (sacci pneumatici) are thin-walled cavities that serve as component of gaseous exchange attached to lungs by connective tissue or smooth muscles. Walls of sac are composed of simple non stratified squamous epithelium, elastic, collagen fibres, few blood vessels and are covered by Tunica serosa partially. Anatomically, there are 9 air sacs (Powell, 2000), among which clavicular air sac is unpaired and penetrate humerus bone. Most of them communicate with lobar bronchi via ostia or perforations (except abdominal sac that had communication with principal bronchi and plays key role in ventilation of lungs). Based on movement of air during inspiration and expiration, sacs categorized into 2 groups:

Cranial air sac- cervical air sac (smallest), clavicular air sac, anterior thoracic air sac (contract on second expiration).

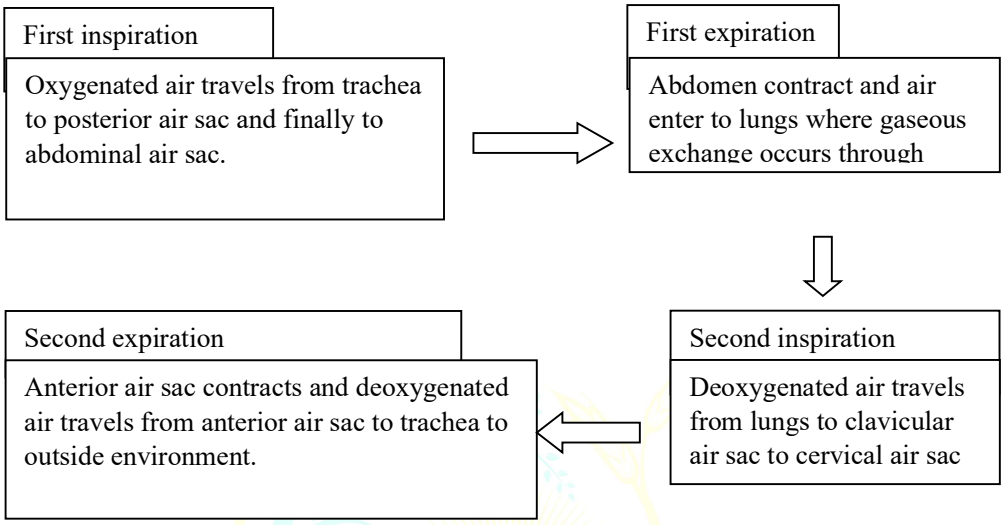
Caudal air sac- posterior thoracic air sac (expands on first inspiration), abdominal air sac (largest air sac).

II. MECHANISM OF RESPIRATION

Respiration is assisted by movement of sternum, ribs and expansion and contraction of chest and abdomen. There is coordinated sequential unidirectional flow of air through air sacs and gaseous exchange take place within the lungs. Due to the attachment of lungs with air sacs and their location within the thoracic cavity, the movements within thoracic cavity are directly reflected within air sacs. In case of birds there are 2 cycles of inspiration and expiration to carry out one respiratory cycle. The air sacs do not perform gaseous exchange but act as stoppage to hold air within the sacs at the time when parabronchi within the lungs perform gaseous exchange.

During first inhalation, the thoracic cage increases both dorsoventrally and transversely in diameter, as a result the oxygenated air travels from trachea to caudal air sac (after expansion or inflation of posterior thoracic air sac) with the assistance of left and right principal and lobar bronchi followed by first exhalation in which the abdomen contracts and it forces oxygenated air from caudal air sac to enter into lungs

where exchange of gases between parabronchi (within the lungs) and blood capillaries occur. During second inspiration, deoxygenated air passes from lung (parabronchi) to clavicular, cervical, anterior air sacs (with the help of lobar bronchi). In second expiration, the anterior air sac contracts and air enters trachea to nostrils.



III. FUNCTIONAL AND CLINICAL ASPECT OF AIR SACS

1. Nonvascular and plays role in holding of air during process of respiration (gaseous exchange)
2. Susceptible target for infection
3. Thermoregulation
4. Unidirectional ventilation to birds
5. Anatomically provide highly efficient option for diagnostic and therapeutic intervention for clinicians.
6. Provide contact to most of the bird's body.
7. Lightens the body and provide buoyancy
8. Increases respiratory efficiency
9. Maintain body equilibrium
10. Assist in vocal sound production by syrinx
11. Used for identification of internal organs during endoscopy

IV. VARIATIONS IN AIR SAC AMONG DIFFERENT BIRDS

The air sac occupies more than 30% volume of thorax and abdomen of birds (zwart *et al*., 2021). In pigeons (*Columbia livia*), the wall of air sac contains thin layer of connective tissue arranged in perpendicular manner and are covered by flat epithelium while in Quails there is single layer of connective tissue(zwart *et al*., 2021). In general, the cranial air sac is smaller than caudal air sac in terms of volume but in chicken's cranial sac is larger. Also, the abdominal air sacs are smallest in case of kiwi birds (Faux *et al*., 2022). The posterior thoracic air sacs are largest in Ostrich and Humming birds (Stanislaus, 1937; Schmidt-Nielsen *et al*., 1969).

V. CONCLUSION

Though birds have complex respiratory system but the visualization of structures present in this system can be used clinically, as an aid for research or as teaching aid in veterinary field (Petnehazy *et al*., 2024). The presence of air sacs not only increases their respiratory efficiency but also made their body light weight that helped them in flight. The contribution of air sac in respiratory gas exchange is <5% (Harrison, 2009). Also, the syrinx that act as voice

producing organ are vibrated by the air that is generated from clavicular air sac and move out of the system.

REFERENCE

Baumel, J.J. (1993). Apparatus Respiratorius, Handbook of avian anatomy, Second edition, Nuttall Ornithological Club, pp. 274-275.

Burggren, W.W., Fishman, Alfred P., Weibel, Ewald R., Klocke, Robert A. and White, Fred N. (2024, March 21). Respiratory system. Encyclopedia Britannica. https://www.britannica.com/science/respiratory-system

Cynthia M. Faux, Marcie L. Logsdon,Case 26.3 - Air sacculitis, Editor(s): James A. Orsini, Nora S. Grenager, Alexander de Lahunta,Comparative Veterinary Anatomy,Academic Press, 2022, pp 1334-1342, https://doi.org/10.1016/B978-0-323-91015-6.00123-0

Konig, S.E., Korbel, R. and Liebich, H.G. (2016). Respiratory system, Avian Anatomy Textbook and Colour Atlas, Second edition, 5M publishing, pp. 126-128.

Lasiewski, R.C. (1972). Respiratory function in birds. Avian biology, 2:287-342.

Maina, J.N. (2008). Functional morphology of the avian respiratory system, the lung–air sac system: efficiency built on complexity. Ostrich-Journal of African Ornithology, 79(2):117-132.

Maina, J.N. (2022). Perspectives on the structure and function of the avian respiratory system: functional efficiency built on structural complexity. Frontiers in Animal Science, 3:851574.

Peernel Zwart, Jaime Samour, The avian respiratory system and its noninfectious disorders: A review, Journal of Exotic Pet Medicine, Volume 37,2021, pp 39-50. https://doi.org/10.1053/j.jepm.2021.02.004

Petnehazy, O., Csoka, A., Fajtai, D., Echols, S. and Donko, T. (2024). CT-based 3D reconstruction and basic anatomical analysis of the 3D anatomy of the air sac system in domestic birds. Anatomia, Histologia, Embryologia, 53(2):e13022.

Powell, F.L. (2000). Respiration. Sturkie's Avian Physiology, 233-264. https://doi.org/10.1016/B978-012747605-6/50011-0

Proctor, N.S. and Lynch, P.J. (1993). Respiratory system, Manual of Ornithology, first edition, Yale University Press, pp. 210-213.

Ross, M.J. (1898). Special Structural Features in the Air-Sacs of Birds. Transactions of the American Microscopical Society, 20:29–40. https://doi.org/10.2307/3221243

Scanes, C.G. and Dridi, S. (2022). Respiratory system, Sturkie's Avian Physiology, Seventh edition, Elsevier publisher, pp. 446-448.