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Transmission Electron Microscopy Study on the Gas Exchanger of the Migratory Quail (*Coturnix coturnix coturnix*) and Farmed Quail (*Coturnix coturnix japonica*)

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ABSTRACT

Birds have an extra ordinary respiratory system which plays an important role in keeping the body temperature constant. The abilities of birds to sustain flight and to fly in the thin air of high altitude are striking evolutionary accomplishments. The respiratory system is vital to these strenuous feats and thus most research on the form, function and adaptive significance of the avian lung has rightly on adaptations that enable rapid rates exchange. Morphologically, the avian respiratory system is separated into the lung (the gas exchanging part) and the air sacs (the non respiratory part). Lung tissues of the migratory quail and the farmed quail were subjected to standard processing for transmission electron microscopy. The results reported differences in the number and form of the air capillaries (Acs) and blood capillaries (Bcs). The blood gas-barrier (BGB) was thinner in the migratory quail than that of the farmed quail. The lung of the migratory quail is very efficient because of the presence of an extremely thin blood gas barrier than that of the farmed quail. This would contribute to the remarkable to expend energy during flight, especially at high altitude by the migratory quail which flies for longer distances, and indicate that structural adaptations may occur in the avian lung in response to functional demands.

Key words: Ultrastructure, Lungs, Birds, Quails

INTRODUCTION

Quail is a small avian species belongs to family Phasianidae. The migratory European coturnix or common quail as they are sometimes called are widely distributed in Europe, Africa and Asia. They are classified, *Coturnix coturnix* and include several insular subspecies of which one is found in the Azores and another on the island of Madeira. Japanese quail, *Coturnix c. japonica*, from which our domestic quail have been developed, are sometimes considered to be a different species but are in fact identical to European quail.

The abilities of birds to sustain flight and to fly in the thin air of high altitude are striking evolutionary accomplishments. The respiratory system is vital to these strenuous feats and thus most research on the form, function and adaptive significance of the avian lung has rightly on adaptations that enable rapid rates of exchange (Maina, 1989).

The gas exchanger of birds consists of a compact lung nestled dorsally amongst and immediately ventral to the thoracic ribs and connected to a number of air sacs. For efficient gas exchange by passive diffusion, a thin and extensive BGB is necessary. Maina and King (1982) suggested that the avian lung has evolved a very much thinner blood-gas barrier than that of any other known air breathing vertebrate, but without sacrificing the structural stability of the barrier. This adaptation maximizes the diffusing capacity of the lung, and minimizes the cost in the oxygen incurred by the metabolism of the barrier itself. Thus, birds have achieved perfection in barrier design, and this would contribute to their remarkable to expend energy during flight, especially at high altitude. The objective of this study was to investigate the ultra structural characteristics of gas exchanger of the lung of migratory and farmed quail and the differences in the lung of these species.

MATERIALS AND METHODS

The wild or migratory quail (*Coturnix coturnix coturnix*) and the farmed quail (*Coturnix coturnix japonica*) were caught using a mist net and were sacrificed. Samples from the lungs were fixed in 2.5% gluteraldehyde at 4 ºC in 0.1 M Na cacodylate buffer at pH 7.4 for about 2 - 3 hrs. The tissues were then washed in cacodylate buffer several times for about 30 min. The samples were post fixed for 2 hours in 1% osmium tetroxide at pH 7.4. The samples were then washed in the buffer several times overnight at 4 ºC and then passed through increasing concentrations of ethanol, rinsed with 100% propylene oxide for 1 hr. and embedded in Araldite epoxy resin (Luft, 1961). Ultrathin sections were cut at 50 - 60µm thickness, mounted on copper grids, and stained with uranyl acetate and lead citrate (Venable and Coggeshall, 1965). Photographs were taken with a JEOL electron microscope at an accelerating voltage of 80 kVat Electron Microscopy Unit in Faculty of Science, Alexandria University.

RESULTS AND DISCUSSION

The structure of the gas exchangers has largely been refractory. There are no tissues or cells that are absolutely distinctive to the respiratory organs, e.g., hepatocytes are to the liver, podocytes to kidneys, osteocytes to bone, erythrocytes to blood, or neurons to nervous tissue. An unspecialized surface, e.g., a cell membrane is the most elementary but practical gas exchanger (Mangum, 1982). The structure of the gas exchangers must be read and interpreted carefully, especially in the so called ‘primitive’ organisms. The population of cells collectively called pneumocytes has

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very few common morphological characteristics that are specific to the respiratory role of the organs in which they are found (Maina, 2000). The most perplexing structural properly of the avian lung pertains to its exceptional mechanical strength, especially that of tiny terminal respiratory units, the air and the blood capillaries.

The exchange tissue of avian lung consists of the air capillaries (Acs) and the blood capillaries (Bcs). The Acs and Bcs form a complex network. Air capillaries were straight, blind ending tubules while Bcs were direct tubules that run in words parallel to and in contact with the Acs. The fine structure of the lung of the investigated species is differing in some features. In this study, the air and blood capillaries showed a great variation in the size, number and shape in the two species. The lung of migratory and farmed quails contains air capillaries (Acs) which are surrounded by blood capillaries (Bcs). The Acs have larger size in migratory quail compared with the Acs in the farmed quail lung which are small (Fig. 1 a and b). The number of Ac in the lung of the migratory quail was larger than that of farmed one (Fig. 1. a and b).

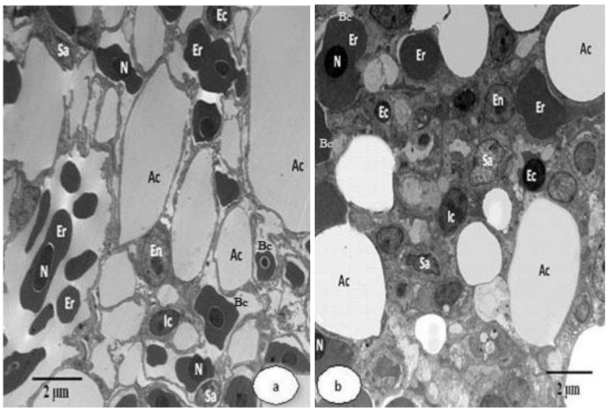

Figure (1):

a:Transmission electron micrograph of the lung of migratory quail, showing blood capillaries Bc containing Er erythrocytes suspended in Ac air capillaries, En endothelial cell, N nucleus, Sa squamous atrial cell, Ic interstitial cells and perikaryon of an Ec epithelial cell.

b:Transmission electron micrograph of the lung of farmed quail, showing blood capillaries Bc containing Er erythrocytes suspended in Ac air capillaries, En endothelial cell, N nucleus, Sa squamous atrial cell, Ic interstitial cells and perikaryon of an Ec epithelial cell.

The blood capillaries contained numerous nucleated Erythrocytes (Er) and the endothelial cell (Ec) appeared in the both species. (Fig. 1. a and b). Air and blood capillaries allow the exchange tissue of the investigated avian respiratory system to be ventilated continuously and unidirectionally, granting exceptionally high respiratory efficiency (Schied, 1979; Fedde, 1980). In addition, one of the most confounding observations that have been made on the functional design of the avian lung is undoubtedly that the air capillaries possess remarkable stability which protects them against collapse even when the respiratory system is compressed (Macklemet *et al*., 1979. Maina and Jimoh, 2013).

Powell *et al.* (1985) also reported that increasing the blood flow to one lung did not cause any significant change in the lung's vascular resistance and that the blood capillaries did not distend after the doubling of the cardiac output to one lung. A laminated membrane surface was observed on the epithelial cells lining the tertiary bronchi and atria of the lungs. The laminated surface, which varied greatly in thickness and number of lamination was discontinuous and didn't line the entire lumen. Lamellar osmiophilic inclusions observed in the cytoplasm of epithelial cells (Fig. 2 a and b).The surface activity of the trilaminar substance in the wall of the air capillaries may therefore be of little importance in preventing collapse. The constant presence of the trilaminar substance as an integral compound of the lining layer on the air capillaries might be to prevent excessive transudation of plasma from blood capillaries into the air capillaries. The trilaminar substance might account to a large degree for the stability of the air capillaries. The role it plays is obscure (Pattle, 1978). It is suggested that the laminated membrane surface is intimately associated with the formation of the osmiophilic inclusions.

Maina and King (1982) reported that the avian lung has evolved a very much thinner blood gas-barrier than that of any other known air breathing vertebrate, but without sacrificing the structural stability of the barrier. This adaptation maximizes the diffusing capacity of the lung and minimizes the coast in oxygen incurred by the metabolism of the barrier itself. Birds have achieved perfection in barrier design, and this would contribute to their remarkable to expand energy during flight, especially at high altitude.

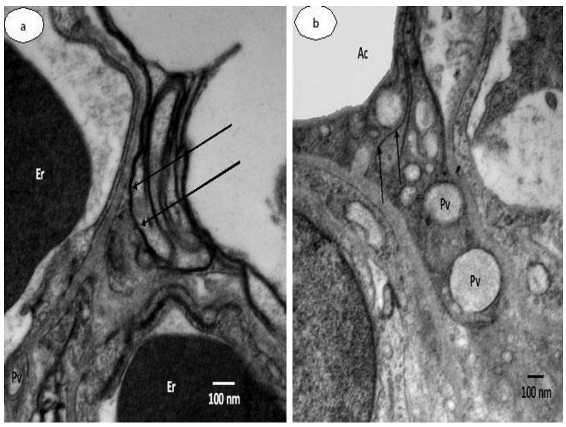

Figure (2):

a: A higher magnified part of the lung of migratory quail, showing Er erythrocytes, Pv pinocytotic vesicle and arrows showing branches of laminated membrane surface.

b: A higher magnified part of the lung of farmed quail, showing Ac air capillaries, Pv pinocytotic vesicle and arrows showing branches of laminated membrane surface.

The blood gas barrier in the investigated species composed of endothelium, basal lamina, and a squamous epithelium lining the air capillaries (Fig. 3a and b). A single basal lamina was always found between the endothelium and epithelium of tissue barrier. The epithelial lining cell was extremely thin. The three layers of the BGB (endothelium, interstitium and epithelium) were thinner in the migratory quail (0.075 µm) than in farmed quail (0.542 µm) (Fig 3. a and b). The thinner thickness may be contributed to the high oxygen requirements to expand energy during flight for longer distances, this agrees with Maina *et al.* (1989). Pinocytotic vesicles or inclusions were sometimes visible in the endothelium and epithelium of BGB. The vesicles were larger and more common in the endothelium (Fig. 3a and b).The osmiophilic inclusions were first observed in epithelial cells during preliminary of phagocytosis in the avian lung (Tyler and Pangborn, 1964). In the current study, the granular cells are present in both species, which are steady elements in phylogenesis, They manufacture and discharge osmiophilic lamellar inclusions which are considered to be the precursor of the surfactant responsible for alveolar stability (Gil and Reiss, 1973).

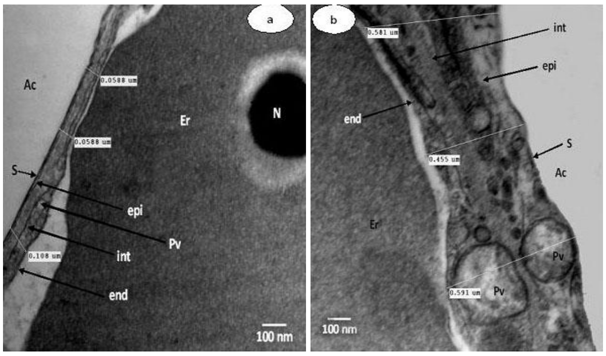

Figure (3):

a: A higher magnified part of blood-gas barrier (BGB) of migratory quail lung, showing the constituent of the (BGB), Ac air capillary, Bc lumen of blood capillary, Er erythrocytes, N nucleus, S surface layer, epi epithelial cell layer, int interstitial space, end endothelial cell layer and Pv pinocytotic vesicle.

b: A higher magnified part of blood-gas barrier (BGB) of farmed quail lung, showing the constituent of the (BGB), Ac air capillary, Bc lumen of blood capillary, Er erythrocytes, S surface layer, epi epithelial cell layer, int interstitial space, end endothelial cell layer and Pv pinocytotic vesicle.

CONCLUSION

In conclusion, the study of fine structure of gas exchanger of the lung of both farmed and migratory quails showed that their lungs affected by their life style behaviour and also oxygen requirement.

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