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Research Article



Anatomical studies on the lung and the air sacs in domestic geese (*Anser anser domesticus*)

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Abstract

In the present study, ten healthy adult domestic geese (*Anser Anser Domesticus*) were used. The morphology of the air sacs (*Sacci pneumatici*) was investigated by using latex neoprene injection and hard cast preparation. The lung (pulmo) was paired, small in size, triangular in shape and not lobed. The geese had nine air sacs; single clavicular sac and paired cervical, cranial thoracic, caudal thoracic and abdominal sacs. The origin, shape, relationships and diverticula of each sac was described and compared with that of other birds.

Keywords: Lung, Air sac, Anatomy, Domestic geese.

Introduction

The air sacs are blind, thin walled enlargement of the bronchial system that extend beyond the lung in close relationship to the thoracic and abdominal viscera (*Nickel, et al., 1977; Powell, 2000 and Dyce et al., 2002*). They added that diverticula from the air sacs invade some bones or extend between the skeletal muscles and around visceral organs.

The air sacs responsible for pulmonary ventilation on inspiration and expiration, their poorly vascularized walls deny them a role in gaseous exchange (*Nickel, et al., 1977; Funk et al., 1992; Duncker, 2000; Maina, 2000; Duncker, 2004; O'Connor & Claessens, 2005; Demirkan et al., 2006a, b and Sawad & Udah, 2012*). Moreover, all were agreement in that they lighten the body weight and being broadly dorsal in position, lowering the center of gravity that assisting in the flight or swimming and also they play a role in regulation the body temperature and in voice production. Morphology of the air sacs in several avian species has been well documented. Our studies in domestic geese is aimed to investigate the

anatomical features of the air sac and their relations to lung and pneumaticing bones with document the differences if there and help us in application of inhalation anesthesia for diagnostic or therapeutic purposes as well as air sac cannulation (*Gunkel and Lafortune, 2005*).

Materials and Methods

The present study was carried out on ten adult geese weighing (2-4) kg. The birds were anesthetized by intramuscular administration of (ketamine HCl 60 mg/kg and xylazine 6 mg/kg) then slaughtered. The technique *O'Connor (2004)* was adopted by gentle manual massage was applied ventrolaterally for the abdomen to evacuate the residual air from the pulmonary system and protect the abdominal sacs from rupture. Two different materials were used in the present investigations. Six specimens were injected by trachea with Kem-apoxy No 150 with its catalyst which were mixed by a ratio 2:1 about 150-200 cc. The specimen were legated and suspended in standing

position for 2-3 days in room temperature for solidification and then the soft and bony tissues were macerated by using 30% potassium hydroxide solution for 2-3 days for corrosion and thoroughly washed with water. The hard cast of the lung and the air sacs were differentiated by different acrylic colors. The rest four specimens were injected with colored latex neoprene through the trachea. It immersed in 10 % formalin solution for 3-4 days then dissected to demonstrate the lungs and the relationship of the associated air sacs and its diverticula to various tissues and bones. The obtained results were photographed using digital camera. The nomenclature used was that recommended by the *Nomina Anatomica Avium* (Baumel et. al., 1993).

Results

Geese had two small lungs (Figs.3, 7, 8 and 11/1), similar in shape and size, not lobed, flattened nearly triangular in shape and bright pink in color. Each lung extended in the craniocaudal direction between the first or second to the seventh rib. Its lateral surface closely contact attached to the thoracic wall and its dorsal border presented six deep grooves (Figs.7 and 8/1a).

The primary bronchus or dorsolateral bronchus, *bronchi laterodorsales*, (Figs.7 and 8/2) reached from the caudal border of the lung and continued into the abdominal air sac. The ventrolateral bronchi, *bronchi lateroventrales*, (Figs.7 and 8/3) connected with the caudal thoracic air sac. The ventromedial bronchus, *bronchi medioventrales*, (Figs.7 and 8 /4, 4a, 4b) gave off a three stout branches; the first bronchus supplied the cervical air sac, the third one for the cranial thoracic sac and the fourth bronchus reached to the clavicular air sac.

The present study observed nine air sac; four paired air sacs (cervical, cranial thoracic, caudal thoracic and abdominal air sac and single clavicular sac) were located in the body cavity among the viscera. These sacs had various shaped diverticula found between certain groups of muscles and pneumatic bones of the skeleton of the trunk, the pectoral and pelvic girdle and the limbs.

Saccus Cervicalis

The cervical sac (Fig.3/5) was bilaterally located in the neck on each side of the vertebral column. The sac consisted of two diverticula; the intermuscular diverticula, *diverticula intermuscularia*, (Figs.1, 2, 3 and 5/5a) an elongated part measuring approximately 1-2 cm. long, protruded as spear like shape between the cervical vertebrae and muscle of the shoulder girdle where it was fused with clavicular air sac to form cervicoclavicular sac (Saccus cervicoclavicularis) (Fig.8 /5a') and the vertebral diverticula, *diverticula vertebralia*, (Figs.3 and 5/5b) were the tubular part which lied on lateral aspect of the vertebral column from the 2nd cervical vertebrae to 3rd, 4th thoracic vertebrae that passing along the transverse vertebral canals as diverticula suprasedullaria (Fig. 3/5c). It also aerated the first two ribs.

Saccus Clavicularis

The clavicular sac (Figs.2, 3, 5 and 6 /6) was single and enclosed by the shoulder girdle and sternum. It was located ventral to the lung and cranial to the heart occupying the thoracic inlet. The clavicular sac possessed six diverticula aroused from its caudal part and arranged intra- and extrathoracic. The intrathoracic part of the sac gave off the cardiac diverticula, *diverticula cardiaca*, (Figs.4 and 11/6a) which surround the heart. The sternal diverticula, *diverticula sternalia*, (Fig.6/6b) aerated the sternum and coracoid bone. Four extrathoracic diverticula were observed around the cranial thoracic aperture. The subscapular diverticula, *diverticulum subscapulare*, (Figs.1, 3 and 5/6c) interposed between the scapula and 4th, 5th thoracic vertebrae. The axillary diverticulum, *diverticulum axillare*, (Figs.1, 2, 3, 4 and 6/6d) was observed below the muscles of shoulder girdle and gave off the humeral diverticulum, *diverticulum humerale*, (Figs.5 and 9/6e) that invade the humerus through a pneumatic foramen, *Foramen pneumaticum*, (Fig.9/6e'). Moreover, the clavicular sac detached, the subpectoral diverticulum, *diverticulum subpectorale*, (Figs.1,2,3 and 5/6f) located caudal to the first two diverticula, lateral to the first two ribs and beneath the pectoral muscles.

The thoracic air sacs lied inside the rib cage. There are two pairs- cranial and caudal sacs. **Saccus Thoracicus**

Cranialis

The cranial thoracic sac (Figs. 1, 2, 3, 4 and 8/7) located at ventro-lateral to the lungs, medial to the sternal ribs and lateral to the heart and liver. It was rectangular in shape and smaller than the caudal thoracic sac. This sac gave off diverticula for the second to seventh sternal ribs for aeration (Fig.6/ 7a).

Saccus Thoracicus Caudalis

the caudal thoracic sac (Figs.1, 2, 3, 4, 7 and /8) was asymmetrically located caudo-ventral to the lungs. It was about twice the size of the cranial sac. The caudal portion of the left caudal thoracic sac had relation with the liver and the gizzard. Moreover, it was encircled dorsally by the abdominal sac and ventrally by the cranial thoracic sac.

Saccus Abdominalis

The abdominal sac, (Figs.1, 2, 3, 4, 7, 8, 10 and 11/9) occupied the dorsocaudal region of the coelom, was asymmetrically located as two sacs in the abdomen. Each sac extended from the caudal border of the lungs to pubic bone. Its lateral surface was smooth while its medial surface was irregular and related to the viscera. It aerated the last three ribs and synsacrum and medially possessed a trace of the gizzard. The right abdominal sac was longer than the left one and gave traces to the intestines. Two diverticula derived from the abdominal air sacs; the renal diverticulum, *diverticula perirenalia*, (Fig. 10/9a) extended along the kidneys and invaded the synsacrum. The femoral diverticulum, *diverticula femoralia*, (Fig.11/9b) pneumatizing of the femur and the muscle of pelvic limb.

Discussion

There were variations in the anatomy of the avian respiratory system; most birds had the lung and the air sacs as respiratory pathway. Therefore seems reasonable to compare our finding in domestic geese and those of other investigators as reported by *Getty, (1975)* in turkey, *Funk et al., (1992)* and *Onuk, et al., (2009)* in domestic geese, *Powell, (2000)* and

Duncker, (2004) in chicken, *Demirkan, et al.,(2006b)* and *Sawad and Udah, (2012)* in Japanese quail and *Demirkan, et al., (2006a)* and *EL- Bably, et al., (2014)* in duck.

The present study revealed that the lung was small unlobed pink red that extended in the craniocaudal direction from the first or second to the seventh rib. Its lateral surface was convex and closely contact to the ribs forming six deep grooves. A result which was in agreement with *Duncker, (2000)* and *Dyce et al., (2002)*, while *AL-Mahmodi, (2012)* showed pyramidal shaped lung in pigeon, *Lbe et al., (2008)* described flattened rectangular lung in chicken and turkey and trapezium-shaped lung in duck.

Regarding with the origin of each air sac connected from the lung, our observation and *Dyce et al., (2002)*, *Onuk, et al., (2009)* and (*Sawad and Udah ,(2012)* mentioned that the primary bronchi entered the lungs which gave four groups of secondary bronchi; mediodorsal, medioventral, lateroventral and laterodorsal according to the area they supplied. While *Akester, (1960)* revealed that three ventrobronchi were derived from primary bronchus. The first ventrobronchus connected to cervical and clavicular sacs were called ventrobronchus cervicalis and the largest one was ventrobronchus caudalis that connected to the cranial thoracic sac. *Dyce et al., (2002)* and *Sawad and Udah, (2012)* added that the primary bronchus entered the lung at its ventral surface till its caudal border to the abdominal air sacs.

Concerning to the number of the air sacs in domestic geese; four paired air sacs and one unpaired sac were located in the body cavity among the viscera. Our results agreement with *Getty, (1975)*, *Brown et al., (1997)*, *Boggs et al., (2001)*, *Duncker, (2004)* and *Casteleyn, et al., (2010)* mentioned that the number of the air sacs in duck, goose and pigeon are nine, while *Boggs et al., (2001)* divided the air sacs into cranial and caudal group, the cranial group consisted of paired cervical sacs and cranial thoracic as well as single clavicular and the caudal group comprised from the paired caudal thoracic and abdominal sacs. The results disagreement with *Milson et al., (1992)* explained that the number of the air sacs in Canada's geese was eleven, four paired and three single, the clavicular, dorsal and sacral air sacs. *Getty (1975)* mentioned that there were seven air sacs in turkey, whereas the pair caudal thoracic air sacs are absent. *Akester, (1960)*,

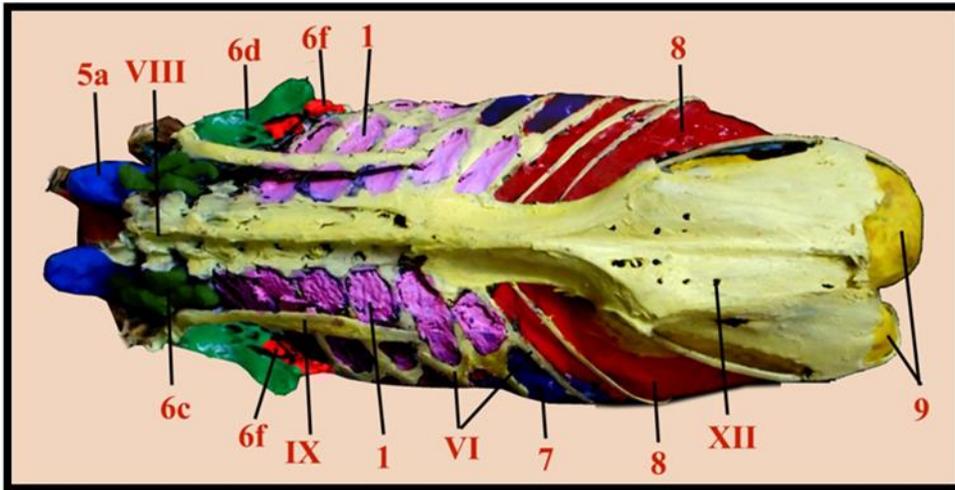


Fig.1: A photograph showing cast of the lung and air sac in geese (dorsal view).

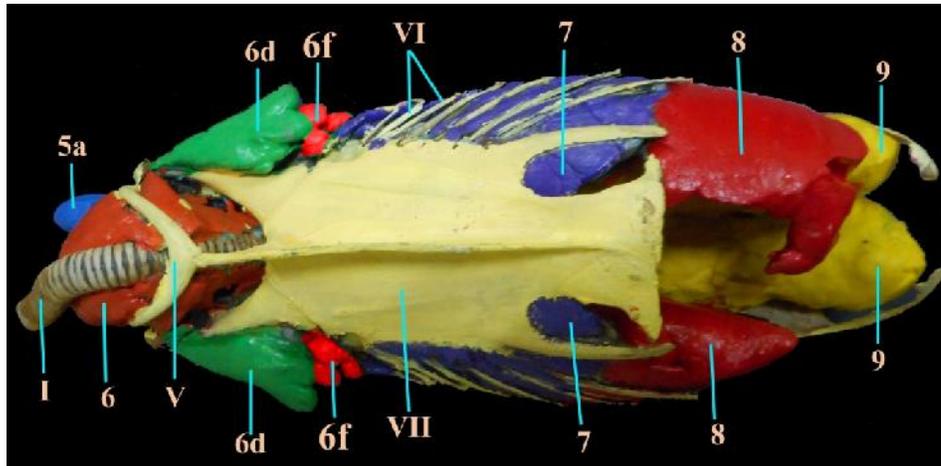


Fig.2: A photograph showing cast of the lung and air sac in geese (ventral view).

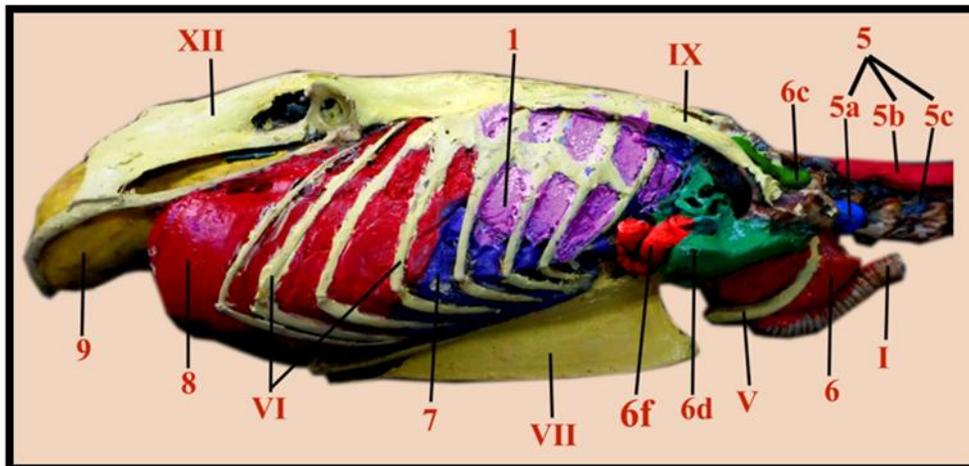


Fig.3: A photograph showing cast of the lung and air sac in geese (lateral view).

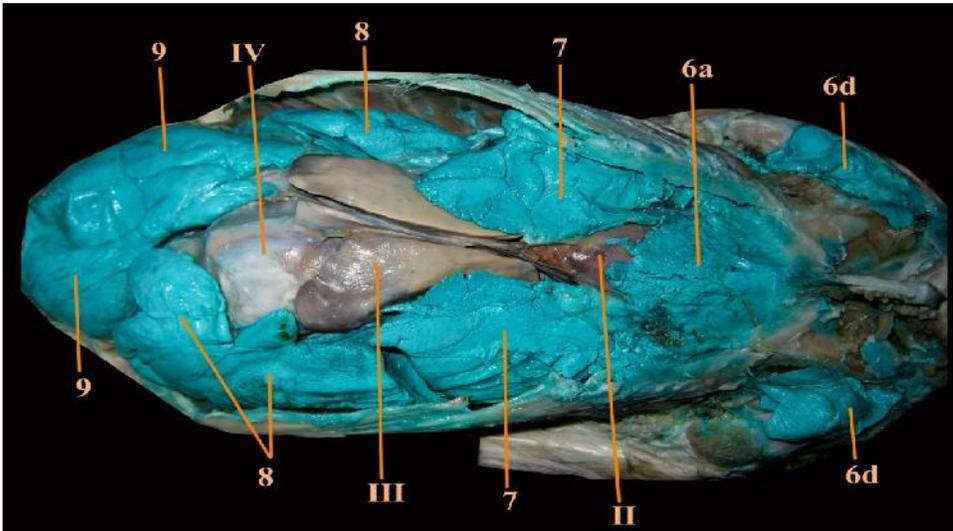


Fig.4: A photograph of latex specimen showing the air sac in geese (ventral view).

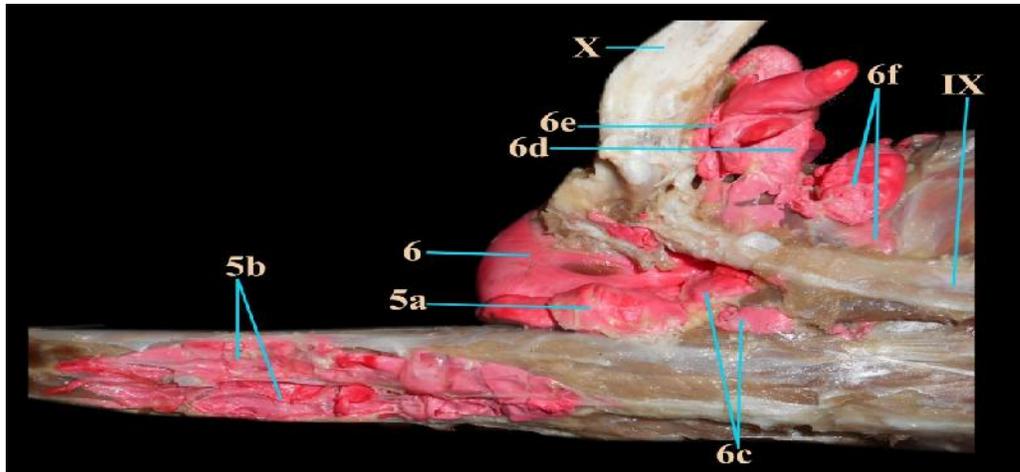


Fig.5: A photograph showing the cervical and clavicular air sac in geese

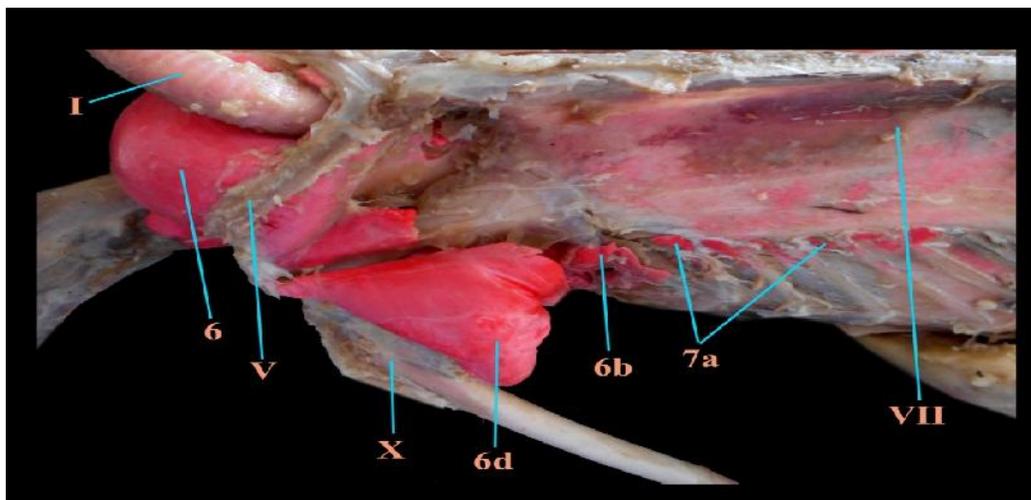


Fig.6: A photograph showing the clavicular air sac in geese.

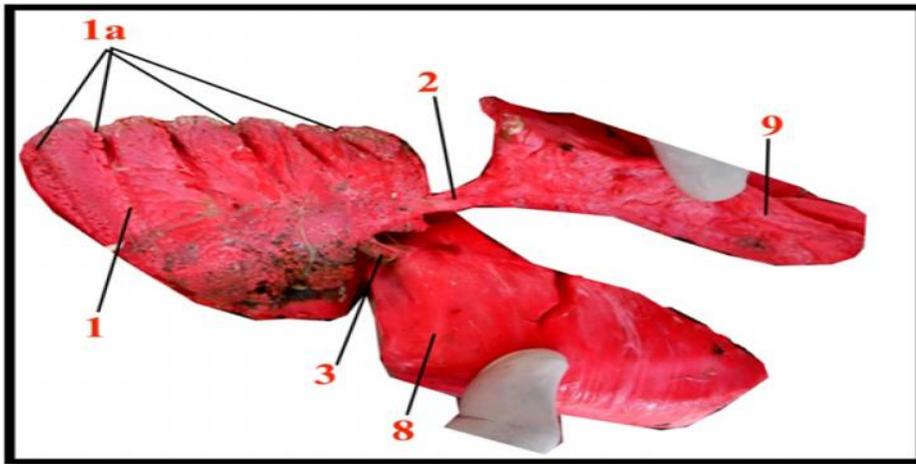


Fig.7: A photograph showing the lung connecting with caudal thoracic & abdominal air sac in geese (Lateral view).

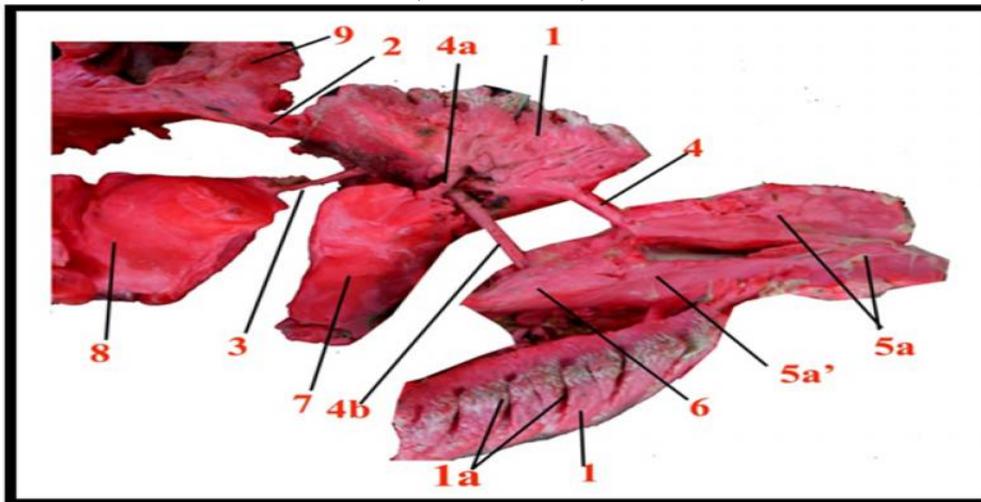


Fig.8: A photograph showing the lung connecting with air sac in geese (ventral view).

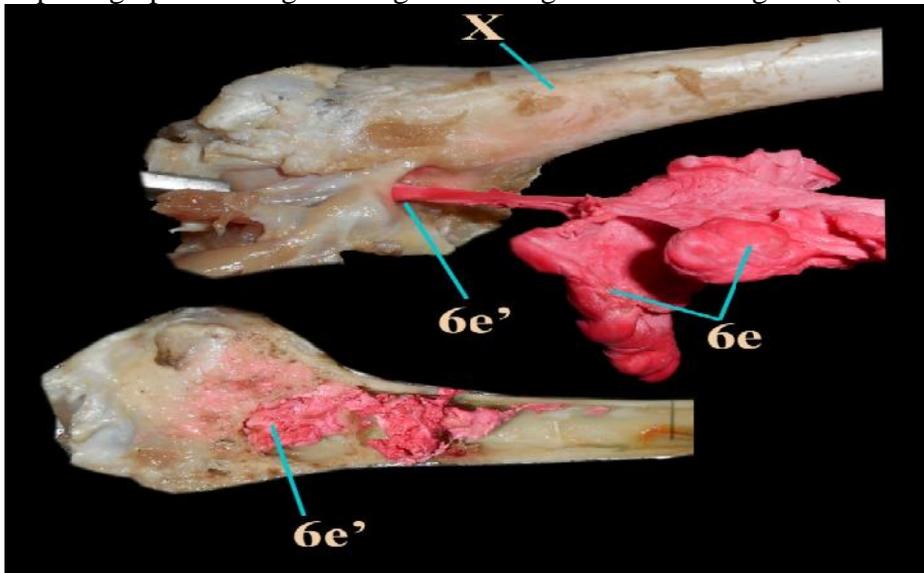


Fig.9: A photograph showing the humeral diverticulum of geese with its pneumatic foramen



Fig.10: A photograph showing the renal diverticulum from abdominal air sacs.

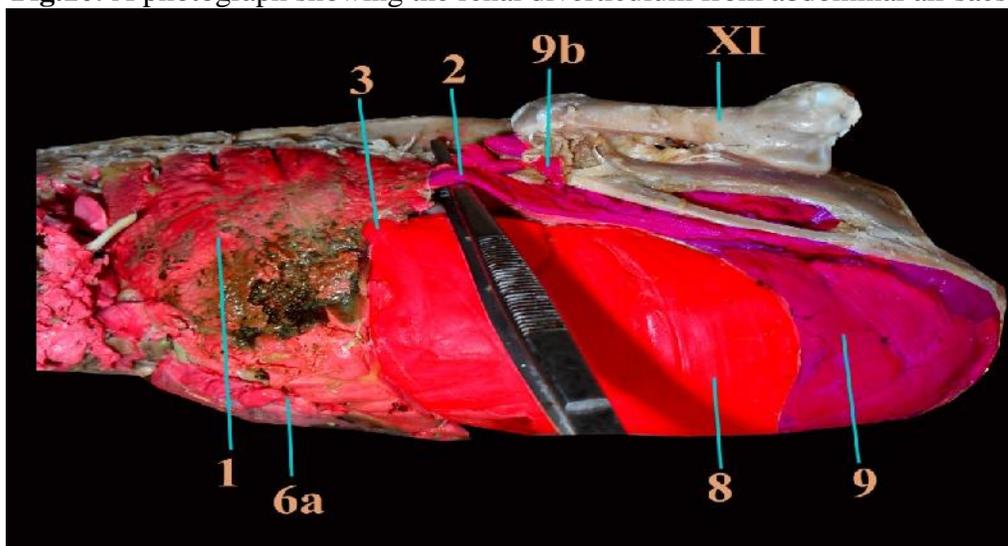


Fig.11: A photograph showing the lung connecting with caudal thoracic and abdominal air sacs with related to femoral diverticulum.

Legend for figures (1-11)

1 -Plumo	7a- Diverticula sternalia
2- Bronchi laterodorsales	8- Saccus thoracicus caudalis
3- Bronchi lateroventrales	9- Saccus abdominalis
4- Bronchi medioventrales I	9a- Diverticula perirenalialia
4a- Bronchi medioventralesII	9b- Diverticula femoralialia
4b- Bronchi medioventralesIII	I- Trachea
5- Saccus cervicalis	II- Heart
5a- Diverticula intermuscularia	III- Liver
5a'- Saccus cervicoclavicularis	IV- Gizzard
5b- Diverticula vertebralia	V- Clavicula
5c- Diverticula supramedullaria	VI- Ribs
6- Saccus clavicularis	VII- Sternum
6a- Diverticula cardiaca	VIII- Thoracic vertebrae
6b- Diverticula sternalia	IX - Scapula
6c- Diverticulum subscapulare	X- Humerus
6d- Diverticulum axillare	XI- Femur
6e- Diverticulum humerale	XII- Synsacrum
6e'- Foramen pneumaticum	XIII- Kidney
6f- Diverticulum subpectorale	
7- Saccus thoracicus cranialis	

Dyce et al., (2002) and *Duncker, (2004)* in fowl, *Powell, (2000)* and *Sawad and Udah, (2012)* in quail and *Demirkan et al., (2006)* in mallard duck, they asserted that the number of the air sacs were eight as unpaired sacs; the cervical and clavicular and paired sacs; the cranial thoracic, caudal thoracic and abdominal air sacs.

The present investigation was in according with (*Demirkan et al., 2006* and *Onuk et al., 2009*), the cervical sac was bilaterally located lateral to the cervical vertebrae. It communicated with the lungs through 1st medioventral bronchi. The sac consisted of three diverticula; the intermuscular diverticula, the vertebral diverticula and the diverticula suprasedullaria. The result was agreement with *Onuk et al., (2009)* demonstrated that the cervical air sac was fused with clavicular air sac to form cervicoclavicular sac in geese.

The present study as well as *Dyce et al., (2002)* and *Onuk, et al., (2009)* revealed that the clavicular air sac located at thoracic inlet. It has two parts; intrathoracic part around heart and extend to the sternum and extrathoracic diverticula which passed between the muscles and shoulder girdle to pneumatize the humerus. Our investigation was incompatibile with *Demirkan et al., (2006)* emphasized that the humerus and the sternum was not aerated and the pneumatic foramen was absent in Japanese quails. *Onuk, et al., (2009)* reported that the extra thoracic diverticula included; the diverticulum subscapulare, diverticulum humerale, diverticulum axillare as our finding but added the diverticulum interpulmonale that found in syrinx.

The current investigation revealed that the paired cranial thoracic air sacs lied ventral to the lung between the sternal ribs, the heart and the liver while the paired caudal thoracic sacs lied caudally between the body wall and the abdominal sacs. The caudal portion of the left caudal thoracic sac in domestic geese had relation with the liver and the gizzard. The caudal thoracic sac was encircled dorsally by the abdominal sac, and ventrally by the cranial thoracic sac. It doesn't contain diverticulum this result similar to what was reported by *Dyce et al., (2002)*, *Kurtul et al., (2004)*; *Demirkan et al., (2006)* and *Onuk et al., (2009)*. While it is dissimilar to *Hadeel, (2003)*, *Khadim, (1996)* and *Akester, (1960)* mentioned that

the caudal thoracic sac in duck was almost as large as the abdominal sac.

In agreement with *Dyce et al., (2002)* and *Sawad and Udah, (2012)*, the paired abdominal air sacs were the largest and occupy the caudodorsal part of the abdominal cavity where contact with the intestine, gizzard, genital organs and kidneys. Each of them sent a diverticulum which ventilated the pelvic bone and synsacrum. The abdominal air sac extended from the lung to the cloaca and has diverticula around kidney and femur. The right abdominal sac was longer than the left one. On the other hand *Demirkan et al., (2006)* observed that, in Japanese quail had diverticulum femorale but didn't enter the femur.

According to (*Boggs et al., 2001*; *O'Connor, 2001* and *Ruben, et al., 2003*) concluded that, the lung of most birds pneumatizes the adjacent thoracic vertebrae and ribs. Although the caudal thoracic air sacs don't pneumatize the skeleton, the cranial thoracic and clavicular sacs invade the sternum, sternal ribs, shoulder girdle and humerus and the cervical air sac diverticula extend caudally along the column to pneumatize vertebrae and *O'Connor, (2004)* stated that the pneumatic features located in distal forelimb elements of screamers (Anhimidae) result from invasion of bone by a network of subcutaneous air sac diverticula spreading distally along the wings that many previous results are in accord with our findings.

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