Ankara Üniv Vet Fak Derg, **56**, 165-170, 2009

Gross anatomy of the respiratory system in goose (*Anser anser domesticus*)*: Bronchi and sacci pneumatici

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Summary: In the study, the macroanatomy of the bronchi and sacci pneumatici were examined in details in 7 domestic mature geese (*Anser anser domesticus*) with 4500-5000 g live weight. The left and right bronchus primarius seperated from trachea branched into four groups of bronchi secundarii that depart from the bronchus primarius called as bronchi mediodorsales (bmd), bronchi medioventrales (bmv), bronchi lateroventrales (blv), and bronchi laterodorsales (bld). The number of bmd, bmv, blv and bld were 4, 10, 10 and 25-30, respectively. It was seen that some of these bronchi were connected with pulmo and some of them were connected with sacci pneumatici. Totally seven sacci pneumatici were found in goose. Saccus thoracicus cranialis, saccus thoracicus caudalis and saccus abdominalis were in pair, however saccus cervicoclavicularis was single. It was determined that the saccus thoracicus cranialis and saccus thoracicus caudalis contained no diverticula and did not aerate any bones. It is first time that branching of the bronchi secundarii and relationship between branches of bronchi secundarii and sacci pneumatici in goose have been observed in the study.

Key words: Anatomy, bronchi, goose, sacci pneumatici.

Kaz (*Anser anser domesticus*) solunum sisteminin makroanatomisi: Bronşlar ve hava keseleri

Özet: Toplam 7 adet 4500-5000 g canlı ağırlığında ergin kaz (*Anser anser domesticus*)'ın kullanıldığı bu çalışmada bronchi ve hava keseleri makroanatomik olarak incelendi. Trachea'dan ayrılan sağ ve sol bronchus primarius'un akciğer dokusunda ilerlerken 4 adet bronchi mediodorsales (bmd), 10 adet bronchi medioventrales (bmv), 10 adet bronchi lateroventrales (blv) ve 25-30 adet bronchi laterodorsales (bld) olmak üzere dört grup bronchi secundarii verdiği saptandı. Bu bronchus'ların bir kısmının akciğerler, bir kısmının da hava keseleri ile bağlantılı olduğu tespit edildi. Kazda üç çift ve bir tek olmak üzere toplam yedi adet hava kesesinin varlığı belirlendi. Bunlardan çift olanların saccus thoracicus cranialis, saccus thoracicus caudalis ve saccus abdominalis olduğu, tek olanın ise saccus cervicoclavicularis olduğu saptandı. Hava keselerinden saccus thoracicus cranialis ve saccus thoracicus caudalis'in diverticulum içermediği ve hiçbir kemiği havalandırmadığı görüldü. Yapılan çalışmayla kazda ilk kez sekonder bronchus'ların dallanmaları, hava keseleri ve bunların birbirleriyle olan bağlantıları detaylı bir şekilde incelenmiştir.

Anahtar sözcükler: Anatomi, bronchi, kaz, sacci pneumatici.

Introduction

Birds differ from mammals due to specific structures in their respiratory system (1, 12, 18). The circulation of the intake air takes place in four stages between pulmones and the sacci pneumatici; two of which are inspiration and the other two are expiration. The trachea in the thoracic cavity, after forming the syrinx, becomes divided into a right and a left extrapulmoner bronchus primarius. Bronchus primarius branches into four groups of bronchi secundarii throughout the pulmo. These are named as bronchi mediodorsales (bmd), bronchi medioventrales (bmv), bronchi laterodorsales (bld) and bronchi lateroventrales (blv) based on the region in pulmo they cover (2, 8, 14). The sacci pneumatici to which the bronchus primarius or bronchi secundarii are connected have a very important role in thermoregulation, in decreasing the body weight during flight and in production of voice (8). In general, there are a total of eight sacci pneumatici located in the body cavity of domestic birds; three double and two single. The single sacci pneumatici are saccus clavicularis, saccus cervicalis and the double sacci pneumatici are saccus thoracicus cranialis, saccus thoracicus caudalis and saccus abdominalis (5, 6, 8). Sacci pneumatici, which contain the diverticula, surround many internal organs and also are connected to a lot of skeletal bones at various levels (11, 13).

Even though it has been stated in literature (8, 12, 14, 17) that the sacci pneumatici show variations morphologically in domestic birds, there was no study

* This study is the part of the doctora thesis "Anatomy of the Respiratory System of Goose (*Anser anser domesticus*)" submitted to Ondokuz Mayıs University, Medical Sciences Institute

found on the anatomical structure of bronchi and sacci pneumatici in goose. Therefore the aim of this study is to reveal the similarities and the differences between the other bird species and geese by examining their bronchi and sacci pneumatici in detail for the first time.

Materials and Methods

In this study, seven 4500-5000 g live weight adult geese (*Anser anser domesticus*) were used. The geese were killed by the intra muscular injection of a combination of diazepam (2-4 mg/kg) and ketamine HCl (20-60 mg/kg) (20). The guideline of the ethical committee of Ondokuz Mayıs University was strictly followed during the procedure. Two of the geese were given a liquid and powder mixture via the trachea for autopolimerisation. Five of geese were given colored-neoprene latex via intratracheal. These materials were kept in cold for two months. Later, the tissues were kept in 40 $^{\circ}$C, 5 % sodium hydroxide (16) and concentrated hydrochloric acide (1, 19) for maseration. At the end, the materials were cleaned by washing and findings were taken. *Nomina Anatomica Avium* (2) was used for nomenclature.

Results

It is observed that the trachea is divided into a right and a left bronchus primarius after forming the syrinx in the thoracic cavity and each of the bronchi enters the pulmo through the hilus in the facies septalis. It is determined that intrapulmonal bronchus primarius that passes through pulmo tissue forms a vestibulum by slightly widening in the middle portion of the pulmo after giving one portion of the bronchi secondarii (Figure 1, Figure 2). The diameter of the vestibulum in the middle is 7.22±0.1 mm. The continued portion called mesobronchus opens directly to a saccus abdominalis (Figure 1). The initial diameter of bronchus primarius is measured to be 5.15±0.06 mm and the diameter of where it opens to the saccus abdominalis is measured to be 4.05±0.06 mm.

Four groups of bronchi secondarii have been determined branching from intrapulmonal bronchus primarius. As shown in Figure 1 and 2, these are bmd, bmv, bld and blv.

The bronchi medioventrales (Figure 1) are the four bronchi secondarii and found to be distributed into the pulmo's dorso-medial. The initial diameter of the thickest bmv1 (Figure 1/1) is measured as 4.7±0.35 mm. After the first 8.44±1.6 mm, bmv1 is separated into two branches as one dorsal (Figure 1/1$'$) and one ventral (Figure 1/1$''$). The dorsal branch is divided into three parabronchus in the dorsal direction and one parabronchus in the medial direction before it connects to the cervical part of the saccus cervicoclavicularis. The parabronchus in the medial direction is in relation with the saccus thoracicus cranialis while the others supply the cranio-dorsal part of the pulmo. The ventral branch of the bmv1 is connected with the cranio-ventral part of the pulmo and the clavicular part of the saccus cervicoclavicularis. It was also found that bmv2 (Figure 1/2), after its origin, is found to be divided into two branches as a dorsal (Figure 1/2$'$) and a ventral (Figure 1/2$''$). The dorsal branch is connected to the dorso-medial part of the pulmo and the ventral branch is connected to the caudo-ventral part of the pulmo with blv1 (Figure 1/a). It is observed that bmv3 (Figure 1/3) is divided into two branches as dorsal (Figure 1/3$'$) and medial (Figure 1/3$''$) at 6.25±0.13 mm after the origin. The branch in the dorsal direction and the branch in the medial direction are in relation with dorso-medial of the pulmo and saccus thoracicus cranialis, respectively. It is determinated that bmv4 (Figure 1/4) is spread into the dorso-medial direction of the caudal part of the pulmo and that it gives a branch to the medial of the ventral part of the pulmo after it leaves the bronchus primarius (8.2±0.3 mm). It is also observed that one branch is in connection to the blv4 (Figure 1/d; Figure 2/d) that opens directly to the saccus thoracicus caudalis.

Bronchi mediodorsales (Figure 1/bmd) are composed of ten branches which line up consecutively. The thickest of these branchs is the first and has a diameter of 4.57±0.26 mm. It is measured that the other branchs' diameters of which decreases as they get closer to caudal are 4.4±0.32 mm, 4.15±0.02 mm, 3.76±0.03 mm, 3.55±0.18 mm, 3.08±0.09 mm, 2.12±0.08 mm, 1.58±0.17 mm, 1.35±0.05 mm and 1.22±0.2 mm, respectively. They supply the dorso-lateral part of the pulmo. A direct connection of the bmd with the sacci pneumatici is not encountered.

The number of blv (Figure 1, Figure 2) is ten. The diameters of blv1, blv2 and blv3 (Figure 1/a, b, c; Figure 2/a, b, c), that are found to be spread into the ventral part of the pulmo, are 3.45±0.25, 2.77±0.13, 3.6±0.51 mm, respectively. It is determined that blv4 (Figure 1/d, Figure 2/d) is separated to two branches after departing from bronchus primarius. The thick branch of blv4 which is 4.06±0.07 mm wide is relation into the saccus thoracicus caudalis. The thin branch of blv4 is 1.66±0.21 mm wide and is spread into caudo-medial of the ventral part of the pulmo. The diameters of blv5-blv10 are similar to the diameter (1mm) of parabronchus (Figure 1/*, Figure 2/*). Blv5, blv6 and last four blv supply to medio-ventral part of the pulmo along with bmv4, medio-lateral part of the pulmo and caudo-lateral part of the pulmo, respectivelty.

Bronchi laterodorsales (Figure 2/bld) originating from the lateral part of the mesobronchus are spread into the lateral part of the pulmo. At the same time, it is determined that the diameters of these bronchi are similar to the diameter of the parabronchus and their numbers vary between 25-30.

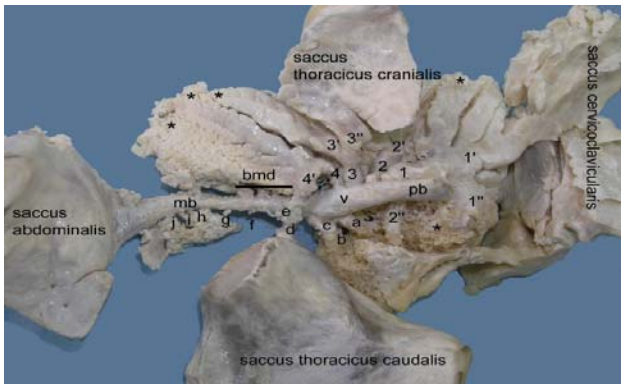

Figure 1: Medial view of the pulmo
bmd: bronchi mediodorsales; mb: mesobronchus; pb: bronchus primarius; v: vestibulum; 1, 2, 3, 4: the branches of the bronchi medioventrales; 1', 1'': the main branches of the first bronchi medioventrales; 2', 2'': the main branches of the second bronchi medioventrales; 3', 3'': the main branches of the third bronchi medioventrales; 4': the spiral branch of the fourth bronchi medioventrales; a, b, c, d, e, f, g, h, i, j: the branches of the bronchi lateroventrales; *: parabronchus
Şekil 1: Pulmo'nun medial'den görüntüsü
bmd: bronchi mediodorsales; mb: mesobronchus; pb: bronchus primarius; v: vestibulum; 1, 2, 3, 4: bronchi medioventrales'in dalları; 1', 1'': birinci bronchi medioventrales'in ana dalları; 2', 2'': ikinci bronchi medioventrales'in ana dalları; 3', 3'': üçüncü bronchi medioventrales'in ana dalları; 4': dördüncü bronchi medioventrales'in spiral kıvrımlı dalı; a, b, c, d, e, f, g, h, i, j: bronchi lateroventrales'in dalları; *: parabronchus

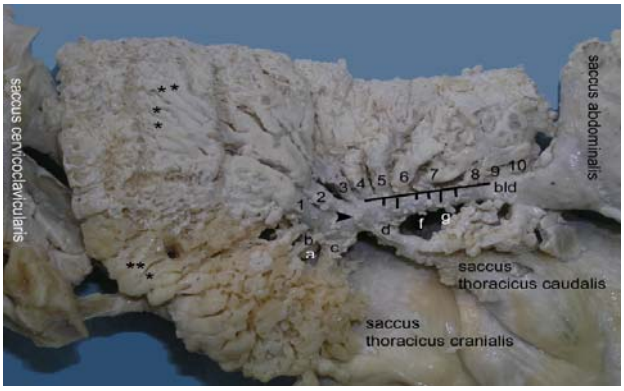

Figure 2: Lateral view of the bronchi secundary
bld: bronchi laterodorsales; 1, 2, 3, 4, 5, 6, 7, 8, 9, 10: the branches of the bronchi mediodorsales; a, b, c, d, f, g: the branches of the bronchi lateroventrales *: parabronchus
Şekil 2**:** Bronchi secundarii'nin lateral görünümü
bld: bronchi laterodorsales; 1, 2, 3, 4, 5, 6, 7, 8, 9, 10: bronchi mediodorsales'in dalları; a, b, c, d, f, g: bronchi lateroventrales'in dalları *: parabronchus

The number of the sacci pneumatici (Figure 3) are a total of seven; three double and one single. Of these, the single one consists of saccus cervicoclavicularis and the double ones consists of saccus thoracicus cranialis, saccus thoracicus caudalis and saccus abdominalis.

Saccus cervicoclavicularis is examined in two parts; cervical and clavicular. The cervical part has two diverticula called as diverticula vertebralia (Figure 3 A) and diverticula intermuscularia (Figure 3 A). Of these, diverticula intermuscularia is found in the shape of a leaf between the cervical muscles and plexus brachialis. Diverticula vertebralia is found outstretched along the cervical and thoracal vertebrae (except atlas and axis). The clavicular part of the saccus cervicoclavicularis has diverticula intrathoracica and diverticula extrathoracica. It is observed that diverticula intrathoracica contains diverticula sternalia (Figure 3 B) and diverticula cardiaca (Figure 3 B). It is concluded that the biggest of this diverticula, diverticula sternalia, is located under the sternum and aerates the sternum and costae between 1-8. It is also determined that diverticula cardiaca is located in the ventral of the diverticula sternalia and wraps the cor all around, more intensely in the basis of the cor. The diverticula extrathoracica has four main diverticula which are spread around the apertura thoracica cranialis. Of these, diverticulum subscapulare is found between the apertura thoracica cranialis and scapula; diverticulum humerale (Figure 3 A-B) is found around the humerus; diverticulum axillare (Figure 3 A-B) is found around the shoulder area muscles; diverticulum interpulmonale is found in syrinx of dorsal in two pieces at right and left between the two pulmones.

The saccus cervicoclavicularis forms one sacs combining with diverticula intermuscularia of the cervical part at the cranial of where the ventral branches of last two cervical and first thoracal spinal nerves of the diverticulum axillare of the clavicular part.

The saccus thoracicus cranialis locating as ventro-medial in the caudal of the pulmo was roughly a rectangle-shape through the lateral. The medial side of the saccus thoracicus cranialis was adjacent to the caudal of the cor, cranial of the hepar and caudal end of esophagus. It is found that saccus thoracicus cranialis, which is almost 1/3 of the saccus thoracicus caudalis, is in relation to bmv1, bmv3 and bmv4 (Figure 1). This sac does not have any diverticulum and is observed that it does not aerate any bones.

The latero-ventral side of saccus thoracicus caudalis has traces of the last four costae. The medial side of this saccus pneumaticus is adjacent to hepar, lien, esophagus, glandular and muscular parts of the gaster (Figure 3 B). It is determined that saccus thoracicus caudalis is related to bmv4 (Figure 1, Figure 2) and does not contain diverticulum.

Saccus abdominalis locating in the dorso-caudal of the body cavity is the biggest sac compared to other sacs (Figure 3). It is determined that this sac that has traces of the last three costae in its latero-dorsal side is aerated directly with mesobronchus in the level of medial of the last proc. uncinati (Figure 1, Figure 2). The medio-ventral side of the left saccus abdominalis is lined towards the muscular part of the gaster. The dorso-

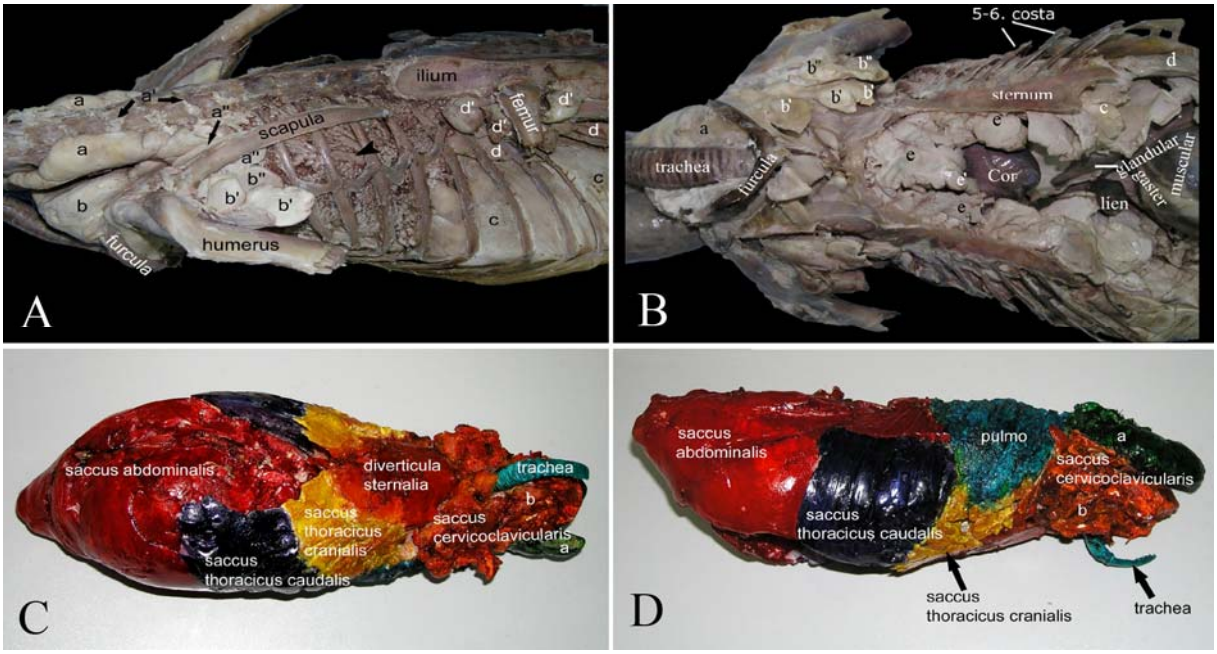

Figure 3: Left lateral (A), Ventral (B-C), Right lateral (D) view of the sacci pneumatici
a: the cervical part of the saccus cervicoclavicularis; a': diverticula vertebralia; a'': diverticula intermuscularia; b: the clavicular part of the saccus cervicoclavicularis; b': diverticulum humerale; b'': diverticulum axillare; c: saccus thoracicus caudalis; d: saccus abdominalis; d': diverticula femoralia e: diverticula sternalia; e': diverticula cardiaca;
Şekil 3: Sacci pneumatici'nin sol lateral'den (A), ventral'den (B-C), sağ lateral'den (D) görünümü
a: saccus cervicoclavicularis'in cervical kısmı; a': diverticula vertebralia; a'': diverticula intermuscularia; b: saccus cervicoclavicularis'in clavicular kısmı; b': diverticulum humerale; b'': diverticulum axillare; c: saccus thoracicus caudalis; d: saccus abdominalis; d': diverticula femoralia; e: diverticula sternalia; e': diverticula cardiaca

medial of the right sac is in contact with the intestinum and carries deep traces of these organs. It is observed that the right and left sacs are almost the same size and locates symmetrically. However, the left sac is divided by a notch into two parts as cranial and caudal. It is found that saccus abdominalis aerates the last two costae and synsacrum. The saccus abdominalis has two diverticulia called as diverticula perirenalia and diverticula femoralia (Figure 3 A) which extends to ren and surrounds the caput femoris, respectively.

Discussion and Conclusion

Bronchus primarius in goose makes an enlargement in the middle parts of the pulmones named as vestibulum, as stated in the literature (8, 10).

Even though, Akester (1960) stated that there were only two groups bronchi secundarii named as anterior and posterior that departs from bronchus primarius in chicken, duck and pigeon, this study determined that there were four groups of bronchi secundarii called as bronchi mediodorsales, bronchi medioventrales, bronchi laterodorsales and bronchi lateroventrales. These finding is similar to the literature (2, 8, 17, 14)

The variation of the diameters between 0,5-2 mm of the parabronchus that did anastomose intensely with each other in the pulmones and departed from bronchi secondarii was stated (1, 2, 8, 14, 17). Nickel et al (1977) stated that this difference in the diameter of the parabronchus related to the body size while King and Mclelland (1984) mentioned that it related to the singing. Akester (1960) stated that the smaller parabronchus diameter would cause more air capillaries in the pulmones and in relation to this, flying will take place easier with the increased respiration surface. Parabronchus diameter was measured as 1mm in the goose with no flying and singing capacity. It was thought that the functional character of the parabronchus diameter can be able to be explained with a comparative study with the flying or singing birds at the same body weight.

The sacci pneumatici consist of saccus cervicalis, saccus clavicularis, saccus thoracicus cranialis, saccus thoracicus caudalis and saccus abdominalis in many bird species (2, 5, 6, 7, 8, 17). Since some of the researchers (5, 6, 8) stated saccus cervicalis as one and some of them (2, 7, 9, 17) stated as double, the numbers of the sacci pneumatici have been determinated as a total of eight or nine. In this study, because saccus cervicalis and saccus clavicularis formed one sacci pneumatici (saccus cervicoclavicularis), the presence of seven sacci pneumatici have been determined similar as in turkey as Getty (1975) stated. Different from this study, Getty

(1975) stated an air sac named as saccus clavicularis medialis, but never mentioned the presence of saccus thoracicus caudalis.

Although the number of bronchi secundarii was generally similar to domestic fowl (8, 14) and Denizli rooster (18), major differences were observed in the bronchi secundarii that are in relation with the sacci pneumatici between the goose and other bird species. The bronchi secondarii which saccus cervicalis and saccus clavicularis are in connection with were stated to be related consecutively to domestic fowl (14, 17) and Japanese quail (3) bmv1, bmv3 and, Denizli rooster (18) and rock partridge (15) bmv1, bmv1 – bmv2. Getty (1975) stated that saccus cervicalis was in relation to bmv1- bmv3 in domestic fowl. In the study, it was observed that these two sacs formed one sac by connecting to each other in the cranial of plexus brachialis and the cervical part of this sac was in relation to dorsal branch of bmv1 while the clavicular part of same sac was in relation to the ventral branch of bmv1.

Saccus thoracicus cranialis was stated to be in relation to bmv3 in domestic fowl (14, 17), bmv1-bmv2 ve bmv4 in Japanese quail (3), mallard duck (4) and rock partridge (15) while in relation to bmv without specifying the number in Denizli rooster (18). In this study, it was determined that saccus thoracicus cranialis was in relation to bmv1, bmv3 and bmv4.

Saccus thoracicus caudalis was stated to be in relation to without any number blv in domestic fowl (14, 17), blv1 and blv2 in Denizli rooster (18), Japanese quail (3) and rock partridge (15), blv3 in duck (8) and bmv4 and blv1 in mallard duck (4). In the study, It was found that saccus thoracicus caudalis was in relation to only blv4 different from the all other species.

It was stated that saccus abdominalis was in relation to blv2, blv3, blv4 and blv5 in mallard duck (4), bmv4, blv3, blv4 ve blv5 in Japanese quail (3). In this study, saccus abdominalis was determined to be in direct relation to mesobronchus as also stated in a lot of literature (8, 14, 17).

Diverticula that the sacci pneumatici have shown differences in animal species (3, 8, 15, 17, 18). While Baumel et al (1993) stated that saccus cervicalis had three diverticula called as diverticula vertebralia, diverticula intermuscularia and diverticula subcutenea, only diverticula vertebralia was mentioned in Denizli rooster (18) and Japanese quail (3). In this study, the cervical part of the saccus cervicoclavicularis was determined to have two diverticula known as diverticula vertebralia and diverticula intermuscularia. It was observed that diverticula vertebralia did not aerate the costae different from what was stated for Japanese quail (3) and rock partridge (15). Also for rock partridge (15), the presence of a diverticula called as diverticulum interpulmonale that reached to the caudal between the pulmones were stated as different from the other species. This diverticula has also been encountered in this study; but the connection was determined to be with clavicular part of the saccus cervicoclavicularis as different from literature (15). Diverticula of the clavicular part of the saccus cervicoclavicularis was observed similar to what Baumel et al (1993) stated, but diverticulum suprahumerale and diverticulum subpectorale were not encountered. In this study, it was observed that saccus thoracicus cranialis and saccus thoracicus caudalis did not contain any diverticula and did not aerate any bones, as coherent with the literature (2, 3, 8, 14, 18).

Saccus abdominalis which has diverticula perirenalia and diverticula femoralia had the biggest volume among the sacci pneumatici as coherent with many other species (1, 2, 4, 6, 8, 17). In the materials examined, it was found that the right and left two sacs that form the saccus abdominalis were as equal size as in rock partridge (15), differently domestic fowl (2, 17), Denizli rooster (18) and Japanese guail (3). Also it was stated that in mallard duck (4), saccus abdominalis was divided into two as cranial and caudal; and the cranial part aerated last three costae and synsacrum. In this study, it was determined that left saccus abdominalis was divided into two parts; but cranial part only aerated the last two costae.

In conclusion, for the first time, the branching of the bronchi secundarii in goose and their relation with the sacci pneumatici were revealed with this study. It is thought that the findings will make important contributions to the anatomy literature.

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Geliş tarihi: 12.05.2008 / Kabul tarihi: 13.06.2008

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