HARRAN ÜNİVERSİTESİ VETERİNER FAKÜLTESİ DERGİSİ

Morphological Comparison of Larynx, Syrinx and Trachea of Some Wild Birds

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Received: 28.02.2024

Accepted: 20.05.2024

How to cite this article: Aksünger Karaavci F, Koçyiğit A, Kanik B. (2024). Morphological Comparison of Larynx, Syrinx, Trachea of Some Wild Birds. Harran Üniversitesi Veteriner Fakültesi Dergisi, 13(1): 48-55. DOI:10.31196/huvfd.1444521.

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Available on-line at: https://dergipark.org.tr/tr/pub/huvfd

Abstract: The presence of both the larynx and syrinx in the respiratory system, the trachea consisting of long and complete cartilage rings, and the presence of air sacs are some of the important features that distinguish birds from mammals. There have been many studies on the larynx, trachea and syrinx as they are the distinguishing features of song and bird vocalizations in many avian species. In the present study, the purpose was to demonstrate the morphological structures of the larynx, trachea and syrinx, which is a sound organ, pigeon, sparrowhawk, falcon, eagle, goose, crow and stork. A total of 48 specimens, were used in the study. The materials were stained with methylene blue for better observation and counting of the tracheal rings. The staining procedure was performed by soaking the materials in alcohol, methylene blue solution and alcohol solutions of different concentrations, respectively. It was observed that the tracheal cartilages were a complete ring in all study species, but there were differences in tracheal length, number of cartilages and dorsoventral flattening. Syrinx was found to be tracheal type in storks and tracheobronchial type in others. As a result, the similarities and differences of the data obtained from pigeon, falcon, sparrowhawk, eagle, crow, goose and stork on larynx, trachea and syrinx due to different hunting, singing and vocal characteristics were revealed.

Keywords: *Avian, Larynx, Macro-anatomy, Syrinx, Trachea.*

Bazı Yabani Kuşların Larinks, Syrinx ve Trakealarının Morfolojik Karşılaştırması

Özet: Kanatlıları memelilerden ayıran önemli özelliklerden bazıları solunum sisteminde hem larinks hem de syrinx'in bulunması, trakeanın uzun ve tam kıkırdak halkalardan oluşması ve hava keselerinin varlığıdır. Ötüş ve kuş seslerinin kanatlılar için ayırt edici özellikler arasında yer alması bakımından birçok kuş türünde larinks, trakea ve syrinx üzerine birçok çalışma yapılmıştır. Bu çalışmada güvercin, atmaca, şahin, kartal, kaz, karga ve leylek türlerinde larinks, trake ve bir ses organı olan syrinx'in morfolojik yapılarının ortaya konulması amaçlanmıştır. Çalışmada toplam 48 örnek kullanıldı. Trakeal halkaların daha iyi gözlemlenebilmesi ve sayılabilmesi için materyaller metilen mavisi ile boyandı. Bu amaçla materyaller önce %70'lik alkolde iki saat bekletildi, distile su ile yıkandı, %0,1'lik metilen mavisi solüsyonunda 15 dakika bekletildikten sonra %50'lik ve %70'lik alkol solüsyonlarında birer saat bekletildi. Çalışılan tüm türlerde trakeal kıkırdakların tam bir halka olduğu, ancak trakeal uzunluk, kıkırdak sayısı ve dorsoventral düzleşme açısından farklılıklar olduğu gözlenmiştir. Syrinx leyleklerde trakeal tipte, diğerlerinde ise trakeobronşiyal tipte bulunmuştur. Sonuç olarak güvercin, şahin, atmaca, kartal, karga, kaz ve leylekten elde edilen verilerin farklı avlanma, ötme ve vokal özelliklerine bağlı olarak larinks, trake ve syrinx üzerindeki benzerlik ve farklılıkları ortaya konmuştur.

Anahtar Kelimeler: *Gırtlak, Kanatlı, , Makro-anatomi, Sirenks, Soluk borusu.*

Introduction

The respiratory system mainly provides in gas exchange, but also plays a role in thermoregulation of body temperature and helps to produce sound (Al-Mahmodi, 2012; Fedde, 1998). The respiratory system in avian is similar in function to other vertebrates but is more developed. There are many differences in the respiratory system organs of birds compared to mammals due to the workload caused by flight requirements, sound production and the desire to move (Heard, 1997; König et al., 2016; Nickel et al., 1977). The presence of both the larynx and syrinx in the respiratory system, the trachea consisting of long and complete cartilage rings, and the presence of air sacs are some of the important features that distinguish birds from mammals (Çalışlar, 1977; König et al., 2016; Nickel et al., 1977).

In avians, the larynx is formed by two single cartilago (cart.) cricoidea and cart. procricoidea and two paired cartilago arytenoidea (Al-Mussawy et al., 2012; Getty, 1975; King and Mclelland, 1984; Öcal and Erden, 2002). Between the cartt. arytenoidea is a narrow slit called the glottis. This cartilage regulates the opening of the glottis through the muscles and is involved in the regulation of the voice (King and Mclelland, 1984).

The trachea connects the larynx to the syrinx and its length varies depending on the length of the neck in avian (Getty, 1975; Kabak et al., 2007; Öcal and Erden, 2002; Taşbaş et al., 1994). The most important difference between the trachea, which consists of cartilages called cartilago trachealis, from mammals is the complete presence of cartilage rings (Getty, 1975; Gündemir and Alpak, 2020; Yılmaz et al., 2016).

Syrinx is the organ that produces sound in birds (Casteleyn et al., 2018; Dewi et al., 2023). There are 3 basic syrinx types according to its topographic location. These are classified as tracheobronchial, tracheal, and bronchial type. Tracheobronchial type syrinx is the most common type in avian (Baumel et al., 1993; Evans, 2016; Ibrahim et al., 2020). In female avians, territorial marking and recognition of family members are of great importance for the socialization of offspring and the attraction of mating partners in males (Casteleyn et al., 2018; Eens and Gorissen, 2005).

There have been many studies on the larynx, trachea and syrinx as they are the distinguishing features of song and bird vocalizations in many avian species. In the present study, the purpose was to demonstrate the morphological structures of the larynx, trachea and syrinx, which is a sound organ, pigeon, sparrowhawk, falcon, eagle, goose, crow and stork.

Materials and Methods

A total of 48 specimens were used in the study. In terms of using animals found dead in nature, the study is not subject to ethical approval. Approval document was received from Bingöl University HADYEK with E-85680299-020-143158 dated 02.02.2024. The study samples were pigeon (*Columbia livia*) (Female(F):10, Male(M):10), goose (*Anser anser*) (F:3, M:5), sparrowhawk (*Accipiter nisus*) (F:3, M:4), falcon (*Falco peregrinus*) (M:1), eagle (*Aquila chrysaetos*) (F:1, M:2), crow (*Corvus corax*) (F:4, M:3) and stork (*Ciconia ciconia*) (F:1, M:1). Dissection was performed according to the dissection technique of Calislar (1977), and the topographic features of the larynx cranialis, trachea and syrinx were recorded. These sections were then removed completely. Excess tissues were dissected. The dorsoventral (DV) and laterolateral (LL) diameters of the tracheal cartilages at the upper-middle-lower 1/3 distances and the length of the trachea were measured with a digital caliper. The materials were stained with methylene blue for better observation and counting of the tracheal rings. For this purpose, the materials were first kept in 70% alcohol for 2 hours, washed with distilled water, kept in 0.1% methylene blue solution for 15 minutes and then kept in 50% and 70% alcohol solutions for 1 hour each. The papillae in the mons laryngealis of the stained materials were counted. The tissues on the larynx cartilages were removed and the cartilage structure was analyzed. Tracheal cartilages were counted and the structure of the syrinx was examined. Anatomical terms were used according to Nomina Anatomica Avium (Baumel et al., 1993).

Results

In all materials examined, the mons laryngealis was observed as a mound on the caudal part of the tongue and at the base of the pharynx (Figures 1 and 2). It was determined that the length of the glottis located above the mons laryngealis and the sulcus laryngealis located just behind the glottis varied according to the species (Table 1). Anatomical results showed that the larynx was similar in structure and position in the species studied. Cartilago laryngealis consisted of single cartilago cricoidea, cartilago procricoidea and paired cartilago arytenoidea. Papillae on the mons laryngealis, which vertically delimit the sulcus laryngealis, were absent in pigeons and stork, but present in other species. In the species examined, the transversal papillae showed different arrangements as single row, two rows, three rows and scattered. In pigeons with single row arrangement, there were 24.7±1.49 papillae in females and 26.2±2.52 papillae in males. In falcon, rostrotransversal papillae (26) and caudotransversal papillae (9) arrangement was observed. In eagles and sparrowhawks, transversal papillae were arranged in 3 (rostral, middle and caudal) rows from front to back. In eagles, the number of papillae in the anterior, middle and posterior arrangement was higher in both sexes than in sparrowhawks. In crows, geese and storks, transversal papillae were scattered. In the crow and goose, they were scattered over the entire mons laryngealis, while in the stork, several papillae were found on the caudal border of the mons laryngealis. The mean standard deviation values of the number of papillae according to species and sex are given in Table 2.

The trachea was found to start behind the cartilago cricoidea and continue to the bifurcatio trachea in the stork, and to the syrinx in other species. The trachea was composed

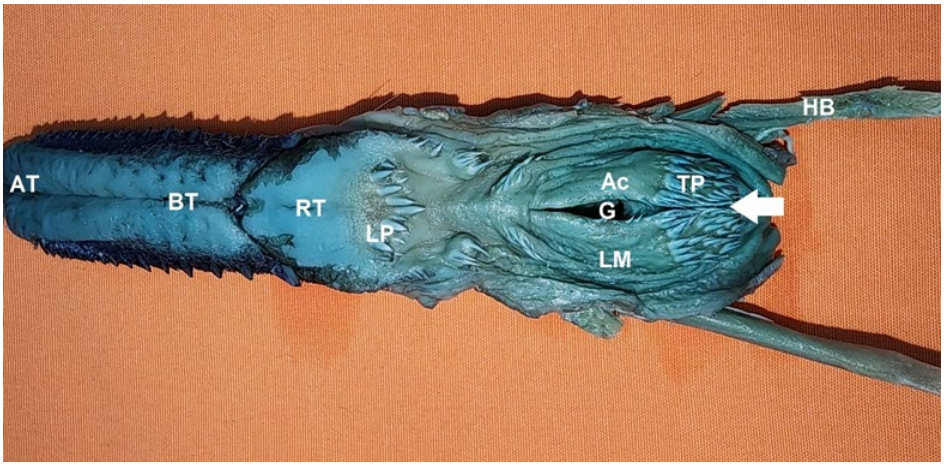

Figure 1. Topography showed location of the larynx in goose, Hyoid bone (HB), at the base of tongue, (AT) Apex of Tongue, (BT) Body of Tongue, (RT) Root of Tongue, (G) Glottis, (LM) Laryngeal Mound, (LP), Laryngeal Papilla, (Ac) Arytenoid cartilage, (white arrow) Sulcus laryngealis.

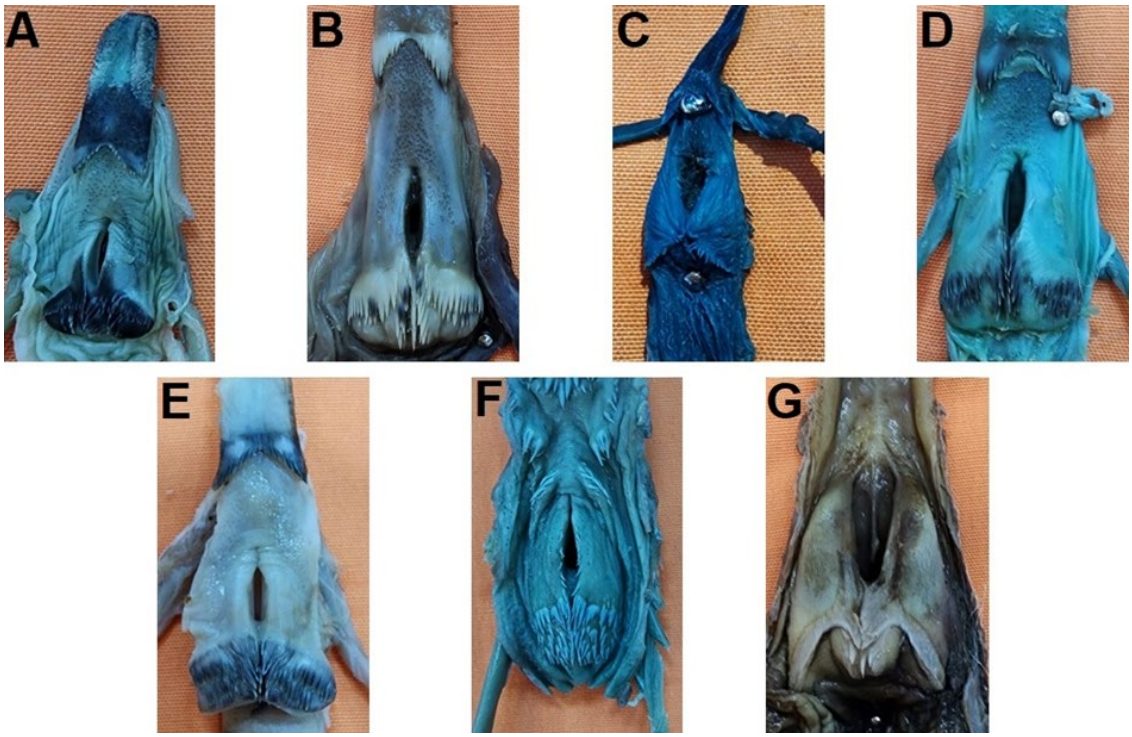

Figure 2. Larynx and papillae by species, (A) Sparrowhawk, (B) Falcon, (C) Pigeon, (D) Crow, (E) Eagle, (F) Goose, (G) Stork.

Table 1. Glottis and sulcus laryngealis length by species and sex.

Species	Glottis length		Sulcus laryngealis length	
	Female	Male	Female	Male
Pigeon	7.13±0.19	6,98±0.52	3,28±0.43	3.12±0.26
Goose	13.62±0.97	15.10±0.58	9.15±0.52	9.10±0.65
Crow	7.24±0.55	6.92±0.67	4.98±0.65	4.12±0.53
Stork	14.67*	13.02*	7.14*	6.12*
Sparrowhawk	4.47±0.54	5.83±0.44	3.12±0.14	3.27±0.53
Eagle	8.85*	7.84±0.17	6.04*	5.55±0.08
Falcon	-	7.31*	-	4.51*

Table 2. Papillae arrangement and number "n"

Species	Sex	Papillae arrangement and number			
		Vertical	Transversal		
Pigeon	Female		Single row (n)		
		-	24.7±1.49		
	Male	-	26.2±2.52		
			Two rows		
			Rostrotransversal		Caudotransversal
Falcon			26		9
	Male	18			
			Three rows (n)		
			Rostral	Middle	Caudal
Eagle	Female	18	28	17	14
	Male	16.5±2.5	28.5±0.5	17.5±1.5	11.5±0.5
Sparrowhawk	Female	11	24	12.5	7
	Male	13	25	12	7
			Messy		
Crow	Female	19	20.75±0.82		
	Male	17	20.33±0.47		
Goose	Female	26	32.33±1.24		
	Male	25	31.6±1.01		
Stork	Female	-	5		
	Male	-	4		

of ring-shaped cartilago trachealis. At the beginning of the neck region, the trachea was located ventral to the esophagus, and then the trachea remained on the left due to the transition of the esophagus to the right. At the entrance of the thoracic region, the trachea was found to be in the ventro-median position again. It was determined that the trachea had different lengths depending on the length of the neck in birds. While the length of the trachea was longer in the female goose than in the male stork, the number of tracheal cartilages was higher in the male stork. Similarly, while the length of the trachea was less in the female eagle than in the male pigeon, the number of tracheal cartilages was higher in the female pigeon. This is thought to be due to the different thicknesses of the tracheal cartilages in the analyzed species (Table 3). The longest trachea was 266.40±4.22 mm in male goose, dorsoventral and laterolateral diameters of cartilago trachealis removed from the upper-middle and lower 1/3 levels of the trachea were different according to the species (Table 4, Figure 3). Cartilago trachealis was found to be dorsoventrally flattened in the upper 1/3 in all species. When DV/LL ratios were analyzed, it was found that dorsoventral flattening was highest in female eagles and lowest in female geese. In the middle 1/3, dorsoventral flattening increased in male falcon and female-male crows, decreased in both sexes in pigeons, storks and eagles, and cartilago trachealis became closer to the circle in sparrowhawks and geese. According to the data obtained from the lower 1/3, it was determined that the cartilago trachealis approached a circle in all species except the sparrowhawk. In sparrowhawks, it was determined that there was a decrease in the degree of dorsoventral flattening compared to the upper 1/3, but the cartilages close to the circle were located in the middle 1/3.

Syrinx was observed to be tracheobronchial type in all species except stork. In the stork, tracheal type syrinx was present. In the stork, 10-11 tracheal rings were located after the syrinx formation and then the bifurcatio trachealis was formed (Figure 4). In geese, the tympanum was shaped like a tube with fusion and ossification of 4-5 cartilages. In other species, the tympanum was shaped by cartilages that were separate from each other in the membrana tympanium lateralis and not a complete ring. It consisted of 3 cartilages in pigeons, 3-4 in falcon and eagles, 3-5 in crows, 4-5 in sparrowhawks and 5-6 in storks. It was determined that bronchus primarius merged from their medial walls at the level of the bifurcatio trachea and formed the pessulus. It was also determined that the first of the bronchosyringeal cartilages extended towards the pessula and connected (Figure 5).

Discussion and Conclusion

Mons laryngealis was reported to have a heart-shaped mound in owls (Demirkan and Özdemir, 2011) and gulls (İnce and Pazvant, 2010), a heart-shaped mound in red hawks (Kabak et al., 2007), Gerze roosters and hens (Onuk et al., 2015), and a heart-shaped mound in Asel roosters and hens (Yılmaz et al., 2016). Similarly, in this study, a heart-shaped hump was found in falcon, sparrowhawks, pigeons, crows and eagles. In geese (Onuk et al., 2010), it was reported to be seen as a hump. In the geese examined, it was observed that the mons laryngealis was an elliptical hump. In the stork, due to the wider glottis, the mons laryngealis had a similar appearance to the right and left lungs, forming a different hump shape from the others.

Table 3. Tracheal measurement length (mm) and number of cartilago trachealis by species and sex.

Species	Sex	Length (mm)	Tracheal cartilage (n)
Pigeon	Female	100.91±5.34	92±6.00
	Male	136.78±5.87	113.40±7.67
Goose	Female	256.33±2.62	136.66±1.69
	Male	266.40±4.22	141.40±2.72
Crow	Female	95.60±3.50	91.25±3.76
	Male	94.50±2.44	90.25±2.41
Stork	Female	255.44	143
	Male	250.32	141
Sparrowhawk	Female	76.10±1.56	76.66±0.69
	Male	86.12±2.11	84.40±3.22
Eagle	Female	132.81	114
	Male	129.19±3.62	102.5±0.5
Falcon	Male	120.65	103

Table 4. Tracheal diamater (mm).

Species	Sex	Diamater					
		Upper 1/3		Middle 1/3		Lower 1/3	
		DV	LL	DV	LL	DV	LL
Pigeon	Female	3.75±0.79	7.01±0.67	3.20±0,76	6.02±0.54	4.63±0.45	7.21±0.56
	Male	4.02±0.96	7.77±0.63	3.86±0.54	7.04±0.85	5.83±0.48	7.65±0.12
Goose	Female	8.69±1.12	9.26±2.02	9.20±1.26	10.97±1.92	9.78±2.23	10.05±2.41
	Male	8.71±0.78	9.35±0.43	9.45±0.37	11.12±0.45	10.05±0.61	10.63±0.09
Crow	Female	3.72±1.15	6.14±0.91	3.63±0.75	5.68±0.26	4.10±0.62	5.12±1.31
	Male	3.72±0.88	6.08±0.93	3.58±0.37	5.71±0.21	4.26±0.43	5.23±1.30
Stork	Female	6.52	13.10	7.29	12.52	8.36	11.40
	Male	6.46	12.95	7.05	12.44	8.18	11.25
Sparrowhawk	Female	3.05±0.56	4.62±0.29	2.97±0.07	3.24±0.11	2.22±0.37	2.96±0.33
	Male	3.15±0.42	4.78±0.12	3.10±0.17	3.46±0.23	2.36±0.32	3.02±0.21
Eagle	Female	3.81	7.85	4.02	6.43	4.68	5.74
	Male	4.16±1.64	7.73±1.21	4.17±1.46	6.53±1.21	4.65±1.75	6.12±1.45
Falcon	Male	4.74	8.62	4.76	8.25	5.65	5.54

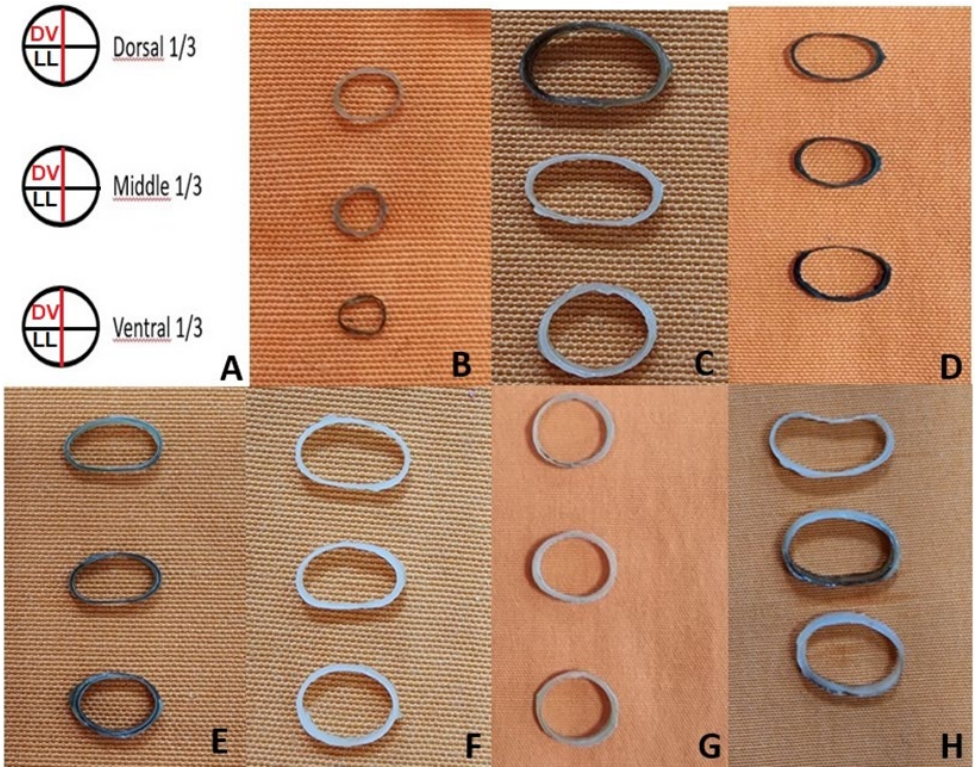

Figure 3. Tracheal cartilage by species, (A) Tracheal cartilage and diameter schematized, (DV) Dorso-Ventral, (LL) Latero-Lateral, (B) Sparrowhawk, (C) Falcon, (D) Pigeon, (E) Crow, (F) Eagle, (G) Goose, (H) Stork.

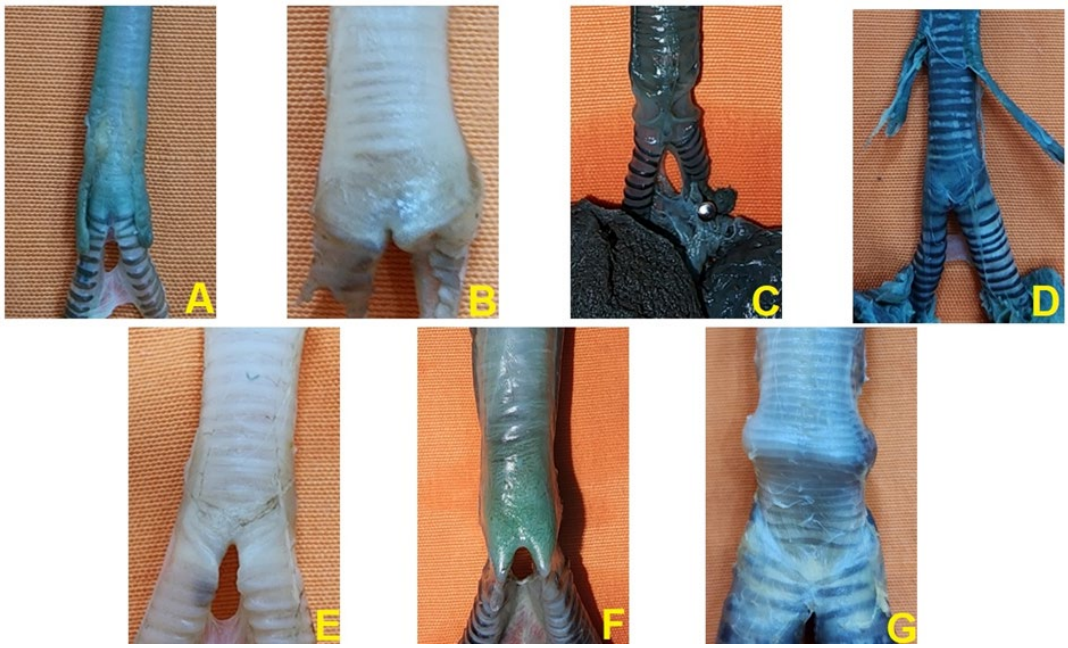

Figure 4. Syrinx by species, (A) Sparrowhawk, (B) Falcon, (C) Pigeon, (D) Crow, (E) Eagle, (F) Goose, (G) Stork.

Figure 5. Dorsal view of the syrinx in the male Sparrowhawk. (1) trachea, (2) sternotracheal muscle, (3) tympanum, (4) interbronchial foramen, (5) interbronchial ligament.

The presence of backward-facing papillae on both sides of the glottis has been reported in the Denizli cock (Taşbaş et al., 1994), Japanese quail (Çevik-Demirkan et al., 2007) and geese (Onuk et al., 2010). Among the species analyzed in this study, it was observed that it was prominently present in geese and crows and as papillae with smaller sizes in pigeons. These papillae were reported in turkeys (Getty, 1975), red hawks (Kabak et al., 2007), aseel roosters and hens (Yılmaz et al., 2016) and gulls (İnce and Pazvant, 2010), but not in storks, falcons, sparrowhawk and eagles.

In the red hawk (Kabak et al., 2007), goose (Onuk et al., 2010), Gerze rooster and hen (Onuk et al., 2015), gull (İnce and Pazvant, 2010), penguin (Taşbaş et al., 1986), and sparrowhawk (Toprak et al., 2016), a medial row of papillae in the sulcus laryngealis was reported. In this study, it was observed that medial papillae were present in all species except pigeons and stork, similar to the literature. In pigeon and stork, no medial papilla row was found in accordance with the data of Yılmaz et al., (2016).

As in many avian species (Baumel et al., 1993; Çevik-Demirkan et al., 2007; İnce and Pazvant, 2010; Onuk et al., 2015; Yılmaz et al., 2016), it was observed that the larynx was formed from the single cart. cricoidea and cart. procicoidea and the paired cart. arytenoidea in all species examined in this study.

In avian, the length of the trachea and the number of rings vary depending on the length of the neck (Heard, 1997; Nickel et al., 1977; Öcal and Erden, 2002; Taşbaş et al., 1994). It was reported to be 188.33±7.63 mm in male ducks and 171.00±3.60 mm in female ducks (Al-Ahmed and Sadoon,

2020), 4.05 cm in quail (Rajathi et al., 2009), 12-13 cm in owls (Demirkan et al., 2011), 8.13 cm in pigeon (Hena et al., 2012), 17.1-22.2 cm in cock (Taşbaş et al., 1994). According to the tracheal length data in pigeons, crows, sparrowhawks, eagles and falcon examined in the study, it is the shortest in female sparrowhawks with 76.10±1.56 mm and the longest in male pigeons with 136.78±5.87 mm, and the data vary according to the species in this range. In storks and geese, the length of trachea was found to be over 250 mm.

It has been stated that the trachea in avian generally consists of 108-126 cartilages (Getty, 1975). It has also been reported that the number is 30-40 in small songbirds and up to 350 in flamingos and cranes (Heard, 1977). It was reported that there were 53-57 cartilago trachealis in magpie (Balkaya et al. 2016), 115-134 cartilago trachealis in gulls (İnce and Pazvant, 2010), 129.66±2.51 and 137.66±2.51 cartilago trachealis in male and female ducks (Al-Ahmed and Sadoon, 2020), 100-130 cartilago trachealis in poultry (Nikel et al., 1977), 117-140 cartilago trachealis in geese (Onuk et al., 2010). In the species analyzed in this study, the number of cartilages varied between 76-143 depending on the species.

It has been reported that the trachea in peacocks is cylindrical and its diameter is the largest in the middle 1/3 and the diameter decreases as it approaches the syrinx (AL-Araji and Mohammed, 2023). It has also been reported that the transversal cross-sectional surface of the tracheal cartilages is round in many species, while it is dorsoventrally flattened in parrots, day- hunting birds and storks (Heard, 1977; King and Mclelland, 1984). Yılmaz et al. (2016) reported that it was dorsoventrally flattened in aseel chickens and roosters at the beginning, became cylindrical by decreasing the diameters in the middle and turned into an oval shape in the last part. In the species examined, it was observed that the tracheal rings were dorsoventrally flattened in the initial part except for the sparrowhawk, while they were more cylindrical in sparrowhawks. In addition, it was determined that the cartilages of the trachea, which started as dorsoventrally flattened, continued to be flattened in pigeons as they approached the syrinx, while the cartilages became rounded in other species.

The structure of the syrinx has been analyzed in many avian species. The most common syrinx type is trachebronchial type. Peking duck (Mohamed, 2017), aseel roosters and chickens (Yılmaz et al., 2016), budgerigars and canaries (Gündemir and Alpak, 2020), male mallard duck (Frank et al., 2007), goose (Onuk et al., 2010), peacock (Al-Araji and Mohammed, 2023) ostrich (Chiappone et al., 2024), and partridge (Alectoris chukar) and Japanese quail (Kara et al., 2023) are among the poultry species showing tracheobronchial type syrinx. Oliveria et al. (2023), observed that the histological characteristis syringes classify them as tracheal type in the White-eyed parakeet and tracheobronchial type in the red-winged tinamou and red-legged seriema. In this study, tracheobronchial type syrinx was observed in sparrowhawks, eagles, falcon, pigeons, geese and crows for both sexes similar to the literature. Casey and Gaunt (1985) reported that tracheal syrinx is mainly found in Furnarioidea (ovenbirds) and some Ciconiidae (storks). The tracheal syrinx of male and female storks in this study is similar to the literature.

As a result, the similarities and differences of the data obtained from pigeon, falcon, sparrowhawk, eagle, crow, goose and stork on larynx, trachea and syrinx due to different hunting, singing and vocal characteristics were revealed.

Conflict of Interest

The authors stated that they did not have any real, potential, or perceived conflict of interest.

Funding

This work has received no financial support.

Similarity Rate

We declare that the similarity rate of the article is %10 as stated in the report uploaded to the system.

Author Contributions

Motivation / Concept: FAK
Design: FAK, AK
Control/Supervision: FAK, AK
Data Collection and/or Processing: AK, BK
Analysis and Interpretation: FAK, BK
Literature Review: FAK, BK
Writing of the Article: FAK, AK
Critical Review: FAK, AK, BK

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