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Research Article

Anatomical Study on the Syrinx of the Lesser Kestrel *(Falco naumanni)*

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ABSTRACT

Infection of falcon by aspergillus fumigatus, asp Flavus and asp Niger cause change in the voice, inability to vocalize or respiratory noises, due to the syrinx lesions, also severe dyspnea occur when obstruction happened. Due to the little available literatures about falcon anatomy, we have done this study to investigate the structure of the lesser kestrel syrinx as it is the voice box in birds which differ from a species to the other. Lesser kestrel *(Falco naumanni)* syrinx is tracheobronchial in type. The tympanum is composed of the last three cartilaginous tracheal simple complete rings. The tracheosyringeal group is formed of four fused single, ossified, special, characteristic rings just before tracheal bifurcation. The bronchosyringeal group is consisted of three paired cartilaginous C-shaped rings on both sides of the tracheal bifurcation; the edges of both first rings are single while the edges of the rest two bronchosyringeal rings are double. The first two bronchosyringeal rings are related medially to the medial tympanic membrane while the last one attached to the interbronchial ligament. The pessulus is a stretched triangle in shape, cartilaginous bar in the median plane of the trachea. The lateral and medial tympanic membranes are complete sheathes closing the trachea bronchial junction of syrinx laterally and medially. The lateral one is larger than the medial one, and both membranes are responsible for the sound production.

Key words: Falcon, Lesser kestrel, Syrinx, Voice box, Anatomy, Bird of prey

INTRODUCTION

The syrinx differs morphologically among different bird species and according to the nature of the cartilage rings contributing to its structure; it is categorized into tracheal, bronchial, and tracheobronchial types. The tracheobronchial type is the most commonly observed type in most birds (Baumel *et al*., 1993). The syrinx in birds is not only responsible for generation of vocalization but also for mating behaviors, in addition to being useful in sex determination, classification of bird species, and determination of their phylogenetic positions (Gaban-Lima and Hofling, 2006).

The tracheobronchial type was commonly collected in ostrich syrinx (Yildiz *et al*., 2003), Bursa Roler Pigeons (Yildiz *et al*. 2005), white turkey (Arican *et al*., 2007 and Khaksar *et al*., 2012), long-legged buzzard (Kabak *et al*., 2007) and quails (Bayram and Liman, 2000 and Çevik *et al*. 2007), Greater Rhea (*Rhea Americana*) (Picasso and Carril, 2013), in guinea fowl (Al-Bishtue, 2014), sparrow hawk (Ozudogru *et al*., 2015), baladi turkey (Ragab *et al*., 2016), black francolin (Al-Aameli and Kadhim, 2017), white pekin ducks (Mohamed R., 2017).

Anatomical structure of syrinx has been investigated in many bird's species such as falconid (Griffiths, 1996), Ostrich syrinx (Yildiz *et al*., 2003), Bursa Roler Pigeons (Yildiz *et al*. 2005), Greater Rhea (Rhea Americana) (Picasso and Carril, 2013), sparrow hawk (Ozudogru *et al*., 2015), baladi Turkey (Ragab *et al*., 2016), chukar partridge (Galliforms) (Erdoğan *et al*., 2015), Sparrow hawk (Ozudogru *et al*., 2015), black francolin (Al-Aameli and Kadhim, 2017), White Pekin Duck (Mohamed R., 2017). The tympanum constituted of the cranial cartilages only (Khaksar *et al*. 2012) or the tympanum compromised both the cranial and the intermediated cartilages (O'Malley, 2005).

MATERIALS AND METHODS

Five specimens from *lesser kestrel (Falco naumanni) of* both sexes and different weight were examined and dissected. Birds carcasses were used which were collected from hospital of faculty veterinary medicine of Cairo, in Egypt. The birds exsanguinated through the *Aa. Comes nervi vagi* which appeared subcutaneously. Two specimens were dissected fresh and then fixed in 10% formalin. The remaining specimens was left in 1%

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methylene blue solution for 15 min then passed through 70% alcohol for two hours for the cartilages to become more evident and then photographed. Nomina Anatomica Avium (1993) was used for nomenclature. All the specimens were photographed by Sony camera h400, 20.1 megapixels, 63X optical zoom cyber shot.

RESULTS

The lesser kestrel *(Falco naumanni*) is a small falcon, which is a bird of prey in the Family: Falconidae, genu: falco, Order: Falconiformes, Species: *Falco naumanni*. The Falcons have a notch on their beaks. Also, the falcon has smaller size than the hawk. The syrinx is situated near the level of the heart (Fig. 1A\2), at the level of the last cervical and 1st to 2nd thoracic vertebrae. The type of syrinx is tracheobronchial. The tympanum (Figs. 2B&C, 3E&D, 4G&6I&J\8) is composed of the last three cartilaginous tracheal simple complete rings, with lesser diameter than the preceding rings.

The tracheosyringeal group (Figs. 2B&C, 3D&E, 4F&G & 6I&J\9) is formed of four fused single, special, characteristic rings just before tracheal bifurcation, the first three rings are complete ossified rings, larger in diameter than the preceding rings, also their dorsoventral diameter is larger so viewed compressed laterally. The last tracheosyringeal ring is incomplete ossified opened ventrally with broad prominent edges toward the subpessular space; its cranial edge is convex while its caudal edge is concave lodging the lateral tympanic membrane.

The bronchosyringeal group (Figs. 2B&C, 3D&E, 4F&G, 5H & 6I&J\10) is consisted of three paired cartilaginous C-shaped rings on both sides of the tracheal bifurcation into two primary bronchi (Figs. 2B&C, 3E, 4F&G, 5H & 6I&J\15), the first ring has concave cranial border which is related to the lateral tympanic membrane(Figs. 3E & 6I&J\12), the edges of both first rings are single while the edges of the rest two bronchosyringeal rings are double(Fig. 6J\10). The first two bronchosyringeal rings are related medially to the medial tympanic membrane (Fig. 5H\16) while the last one attached to the interbronchial ligament (Fig. 3E\14).

The pessulus (Figs. 5H & 4F\11) is a stretched triangle in shape, wide dorsally and narrow ventrally, cartilaginous bar in the median plane of the trachea (Figs. 3D &E\7) and in between the two bronchii (Fig. 5H\15). It is related laterally to the medial tympanic membranes (Fig. 5H\16) and the attached to the first bronchosyringeal rings.

The lateral (Figs. 3E & 6I&J\12) and medial (Fig. 5H\16) tympanic membranes are complete sheathes closing the trachea bronchial junction of syrinx laterally and medially. The lateral tympaniform membrane was located between the last tracheosyringeal and the first cartilage bronchosyringeal ring. The lateral one is larger than the medial one, and both membranes are responsible for the sound production. The medial one lies between the lateral edge of pessulus and the concave border of the first bronchosyringeal ring.

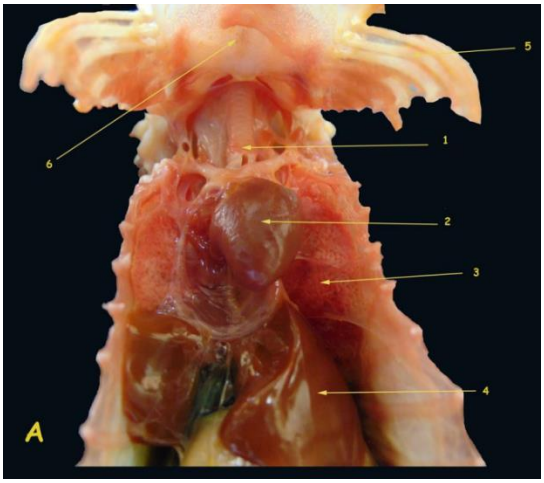

Fig. 1: A; A photograph showing the opened thorax of lesser kestrel *(Falco naumanni)*, ventral view, Fresh specimen.

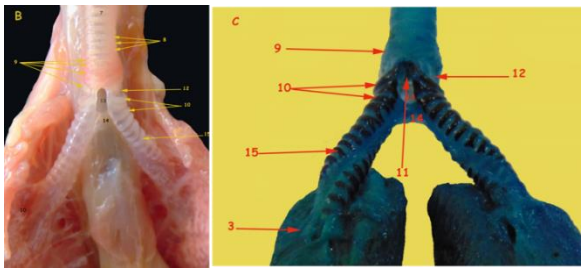

Fig. 2: B; Photograph showing the ventral view of the syrinx of lesser kestrel, fresh specimen. C; Photograph showing the ventrocaudal view of stained syrinx with methylene blue.

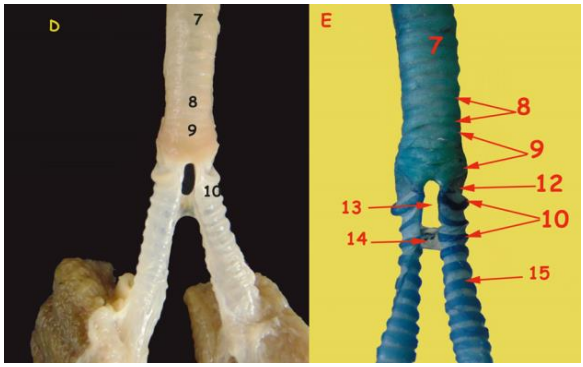

Fig. 3: D; Photograph showing the ventral view of the separated formalized syrinx of lesser kestrel. E; Photograph showing the ventral view of stained separated syrinx with methylene blue.

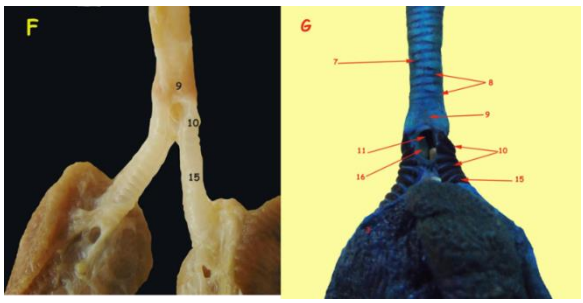

Fig. 4: F; Photograph showing the dorsal view of the separated formalized syrinx of lesser kestrel. G; Photograph showing the dorsal view of stained separated syrinx with methylene blue.

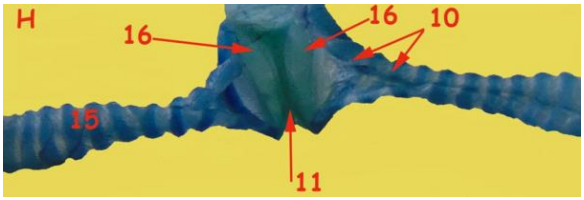

Fig. 5: H; Photograph showing the caudal view of the tracheal bifurcation showing the pessulus, after cutting the interbronchial ligament, in a stained separated syrinx with methylene blue.

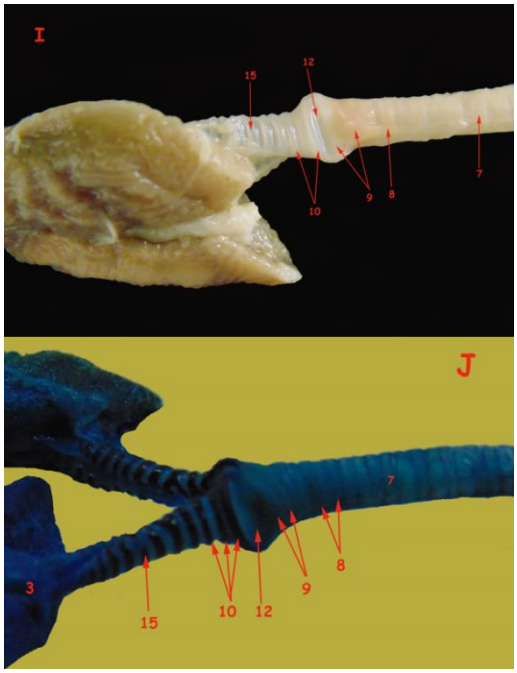

Fig. 6: I; Photograph showing the lateral view of the separated formalized syrinx of lesser kestrel. J; Photograph showing the ventrolateral view of stained separated syrinx with methylene blue.

Legend of figures:

1. The syrinx
2. The heart
3. Lung
4. Liver
5. Sternal ribs
6. Sternum
7. Trachea
8. Tympanum
9. Tracheosyringeal group
10. Bronchosyringeal group
11. Pessulus
12. Lateral tympanic membrane
13. Subpessular space
14. Interbronchial ligament
15. Primary bronchus
16. Medial tympanic membrane

DISCUSSION

The type of the lesser kestrel syrinx is trachea-bronchial, which is similar to the observations on many avian species; in ostrich syrinx (Yildiz *et al*., 2003), Bursa Roler Pigeons (Yildiz *et al*. 2005), white turkey (Arican *et al*., 2007 and Khaksar *et al*., 2012), long-legged buzzard (Kabak *et al*., 2007) and quails (Bayram and Liman, 2000 and Çevik *et al*. 2007), Greater Rhea (Rhea Americana) (Picasso and Carril, 2013), in guinea fowl (Al-Bishtue, 2014), sparrow hawk (Ozudogru *et al*., 2015), baladi turkey (Ragab *et al*., 2016), black francolin (Al-Aameli and Kadhim, 2017), white pekin ducks (Mohamed, 2017).

In the present study, the tympanum of lesser kestrel is composed of the last three cartilaginous tracheal simple complete rings, with lesser diameter than the preceding rings. These findings were approved by Yildiz *et al*. (2003) in ostrich syrinx, Kabak *et al*. (2007) in long-legged buzzard, Ozudogru *et al*. (2015) in the sparrow hawk, and Ragab *et al*. (2016) in baladi turkey. However, the same number of tympanum rings but incomplete rings; the last rings bifurcated into two modified rings to form the tracheosyringeal part, in black francolin (Al-Aameli and Kadhim, 2017). On the other hand, the falconid tympanum was three to eight single rings, fused and ossified, occurred near the trachea-bronchial junction (Griffiths, 1996), Tympanum was formed from 5 oval-shaped cartilage rings in pigeons (Yildiz *et al*. 2005). Moreover, in the chukar partridge (Galliforms) was formed of the last two tracheal incomplete cartilaginous rings (Erdoğan *et al*., 2015) and four C-shaped cartilage rings in white pekin ducks (Mohamed, 2017).

Concerning the tracheosyringeal group was formed of four single rings just before tracheal bifurcation. These findings were in agreement with those of Yildiz *et al*., (2003) in ostrich syrinx, Yildiz *et al*. (2005) in pigeons, Picasso and Carril (2013) in Greater Rhea, Ozudogru *et al*. (2015) in the sparrow hawk. On the other hand, the tracheosyringeal group was formed by two rings, incomplete dorsally in baladi turkey (Ragab *et al*., 2016), Moreover, The tracheosyringeal cartilages in white pekin ducks were eight to ten rings and the last tracheosyringeal rings formed the syringeal bulla in male white pekin ducks, so the syrinx was a symmetrical in the male white pekin ducks forming bulla tympaniformis but in the female duck had no tympanic bulla (Mohamed, 2017). Also, syringeal bulla was recognized in the male duck (Pierko, 2010).

In our study the tracheosyringeal rings was small, narrow, while the tracheosyringeal cartilages of Greater Rhea (Rhea Americana) were broad and conformed a well-developed tympanum (Picasso and Carril, 2013).

Our results clarified that the first three tracheosyringeal rings of lesser kestrel were complete ossified rings and the last tracheosyringeal ring is incomplete ossified opened ventrally with broad prominent edges toward the subpessular space. These findings disagreed with Yildiz *et al*. (2005) who generated that those rings were C-shaped cartilages in pigeons. Moreover, Ozudogru *et al*. (2015) in the sparrow hawk assumed that the tube-shaped tracheosyringeal cartilage commingled with each other and with three other types of cartilage, tracheal, bronchial and tracheobronchial, but not with the hyaline cartilage, which was ossified to create the tympanum.

In our illustration of the bronchosyringeal group of lesser kestrel explored that three paired cartilaginous C-shaped rings were documented. These results were approved by (Yildiz *et al*., 2003) in ostrich syrinx, Picasso and Carril (2013) in Greater Rhea (Rhea Americana) was "C-shaped" and the cart. B1 showed a slightly concave shape, while it was formed from five C-shaped half-ring

cartilage in pigeons (Yildiz *et al*. 2005) and five "C" shape in the sparrow hawk (Ozudogru *et al*., 2015). Moreover, the bronchosyringeal part of black francolin was consisted from four incomplete C shaped rings (Al-Aameli and Kadhim, 2017). On the other hand, the bronchosyringeal cartilages were formed by a pair of three half rings in baladi turkey (Ragab *et al*., 2016), Also, the bronchosyringeal of the chukar partridge (Galliforms) was semi rings in the body of the syrinx (Erdoğan *et al*., 2015).

In the present study, the first two bronchosyringeal rings are related medially to the medial tympanic membrane while the last one attached to the interbronchial ligament. However, Bronchosyringeal Cartilages in white pekin ducks were placed ventrolaterally, while their free ends directed dorsomedially and supported by the medial vibrating membranes (Mohamed, 2017).

In accordance with Al-Aameli and Kadhim (2017) in black francolin, the pessulus was triangular in shape, wide dorsally and narrow ventrally, it was related laterally to the medial tympanic membranes. While the pessulus of Greater Rhea was a thin bar fused with the tympanum (Picasso and Carril, 2013), a wedge shaped ridge situated between the two openings leading to the primary bronchi in the canary (Hartley and Suthers, 1990) and in baladi turkey (Ragab *et al*., 2016) and in white pekin duck (Mohamed, 2017).

The pessulus was cartilaginous bar in the median plane of the trachea and in between the two bronchii. This result simulated those of Ozudogru *et al*. (2015) in the sparrow hawk. On the other hand, the pessulus was soft connective tissue structure in turkey (Bettina and Pablo, 2001 and Khaksar *et al*. 2012) and in ostrich (Yildiz *et al*. 2005) as well as in the pigeon (El-Mahdy 2005). Moreover, the pessulus was made up of a double folded mucous membrane in ostrich syrinx (Yildiz *et al*., 2003) and in pigeons (Yildiz *et al*. 2005). In addition to, the Pessulus was ossified in falconid (Griffiths, 1996), in the canary (Hartley and Suthers, 1990) and in baladi turkey (Ragab *et al*., 2016), in white pekin (Mohamed, 2017).

In the present study, the lateral tympaniform membrane was located between the last tracheosyringeal (tracheal) and the first cartilage bronchosyringeal ring (bronchial). This result simulated those in falconid rings (Griffiths, 1996), in Greater Rhea (Rhea Americana) of Picasso and Carril (2013) and (Mohamed, 2017). On the other hand Erdoğan *et al*. (2015) in the chukar partridge and Ozudogru *et al*. (2015) in the sparrow hawk revealed that this membrane extended from the last cartilage forming the tympanum to the first bronchial cartilage of the syrinx. However, the lateral vibrating tympaniform membrane was reduced into series of transparent strips between the bronchosyringeal rings and their attachments with the tracheosyringeal and bronchial rings in baladi turkey (Ragab *et al*., 2016).

Similar to the observations of Griffiths (1996) in falconid syrinx, the medial tympanic membrane laid between the lateral edge of pessulus and the concave border of the first bronchosyringeal ring.

In agreement with the description of Picasso and Carril (2013) in Greater Rhea (Rhea Americana) that the medial tympaniform membrane was suspended between the free ends of the Bronchosyringeal B1 and B2, and extended, making contact with the pessulus. However, the medial tympaniform membrane covered the medial parts of the first and third bronchosyringeal cartilages and it extended from caudal aspect of the pessulus up to the level of the third bronchosyringeal cartilage (Mohamed, 2017).

The present wok analyzed that there was an interbronchial ligament connected the primary right and left bronchi related dorsally to a subpessular space which was located between the pessulus and interbronchial ligament, those results simulated those of Al-Aameli and Kadhim (2017) in black francolin and Mohamed (2017) in white pekin ducks. On the other hand, the interbronchial ligament was not observed in pigeons (Yildiz *et al*. 2005).

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