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Gross Morphological Studies on the Vertebral Column of Indian Eagle Owl (*Bubo bengalensis*)

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ABSTRACT

Background: Indian eagle owl known to rotate their necks up to 270 degrees in either direction without injuring their vessels running below the head thereby without cutting off blood supply to their brains. The vertebral column in birds carry peculiar features like higher number of cervical vertebrae due to long mobile neck, lumbar and sacral vertebrae fused together giving rigidity which aid in flight. The extensive fusion of vertebral column posterior to the neck provides the required rigidity in the trunk region, this inflexibility feature might reduce weight, as it avoids the need for extensive musculature to maintain a streamlined and rigid body posture during flight. The current study aimed to study the vertebral column of Indian eagle owl in order to understand the anatomical adaptations related to this species.

Methods: The specimens were procured from three Indian eagle owl brought for post mortem examination during the year 2019 to the Department of Veterinary Pathology, Rajiv Gandhi Institute of Veterinary Education and Research, Puducherry. After completion of the post-mortem examination the carcass was collected and macerated as per the standard technique and various measurements on vertebral column bones were measured using vernier calliper.

Result: The study revealed that vertebral column of Indian eagle owl consisted of 14 cervical vertebrae, 7 thoracic vertebrae, 13 to 14 lumbar vertebrae fused with sacral vertebrae forming synsacrum and 7 coccygeal vertebrae. The hypapophyses of the 14th cervical vertebra and first two thoracic vertebrae were trifid in nature specific feature seen in Indian eagle owl. The vertebral column had characteristics features of hypapophyses, transverse process, pneumatic foramen and neural spine which enable the owl to adapt for head rotation and various task involving vertebrae.

Key words: Hypapophysis, Indian eagle owl, Pygostyle, Synsacrum, Vertebral column.

INTRODUCTION

In avian the highly mobile neck is not a simple connection between head and the body but it also aids in movement of head in all possible angles to perform variety of tasks like feeding, preening, sexual display, nest building and combat behaviour. Indian eagle owl are also known as tiger owl found to rotate their necks up to 270 degrees (De Kok-Mercado *et al.* 2013) in either direction without injuring their vessels running below the head thereby without cutting off blood supply to their brains. The vertebral column in birds carry peculiar features like higher number of cervical vertebrae due to long mobile neck, lumbar and sacral vertebrae fused together giving rigidity which aid in flight (De Iuliis and Pulera, 2011). The extensive fusion of vertebral column posterior to the neck provides the required rigidity in the trunk region, this inflexibility feature might reduce weight, as it avoids the need for extensive musculature to maintain a streamlined and rigid body posture during flight. The atlanto-occipital joint provides more mobile articulation compared to mammals which provides considerable rotation of the head in aves. Considering theses peculiar features in aves, present study was focused on gross morphology of vertebral column of Indian eagle owl (*Bubo bengalensis*).

MATERIALS AND METHODS

The specimens were procured from three Indian eagle owl brought for post mortem examination during the year 2019 to the Department of Veterinary Pathology, Rajiv Gandhi Institute of Veterinary Education and Research, Puducherry. After completion of the post-mortem examination the carcass was collected and macerated as per the standard technique (Choudhary and Singh, 2015) and utilized for gross anatomical studies in the Department of Veterinary Anatomy and Histology. The various measurements on vertebral column bones were measured using vernier calliper.

RESULTS AND DISCUSSION

The vertebral Column had total of 42 numbers of bones and entire column was divided into five regions namely cervical

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in the neck, thoracic in trunk, lumbar and sacral fused to form synsacrum which articulates with pelvic girdle forming the back region and coccygeal vertebrae (Fig 1) forms the tail region. The vertebral Column had freely movable vertebrae which assist in the prehensile functions of the beak and numerous fused vertebrae. The numbers of vertebrae in Indian eagle owl are 42 with vertebral formula of C14, T7, L+S13-14, CO7. In Red-crowned cranes, numbers of vertebrae were C17-18, T9-11, S13- 14 and free Co7-8 and Hooded cranes had C17-18, T9-10, S12–14 and free Co6–8 vertebrae (Hiraga *et al.* 2014). Nickel *et al.* (1977) reported the vertebral formula in chicken was C14, T7, S14 to15 free Co 5 vertebrae. The prezygapophyses articular surface had the concave articular surface which was directed downward and inward in the transverse direction and convex in the dorso-ventral direction, whereas the postzygapophyses was directed downward and outward exactly in the opposite direction of prezygapophyses. The postzygapophyses articulate with the prezygapophyses of the corresponding succeeding vertebra in the series to form joints. The prezygapophyses and postzygapophyses allow considerable rotatory movement and bending in the vertical plane.

Cervical vertebrae

In Indian eagle owl, the cervical vertebrae altogether was 14 in number (Fig 2) and they were constructed in such a way that they resemble ‘S’ shaped appearance of the neck supporting the head of owl. The cranial vertebrae move freely forward, while the middle ones back ward and the posterior ones forward allowing the ‘S’ shaped curve of the neck. Neck was so flexible making it possible for beak to reach the uropygeal gland in tail region for the preening purpose. The number of cervical vertebrae varies among wide ranges in birds *viz.* 19 in grebes (Zusi and Storer, 1969), 18 in cormates (Ono, 1980), 14 in japanese quail (Takashima and Mizuma, 1981), 17 in emu (Sridevi *et al.* 2019), 12 in pigeons, 17 in geese, 14 in chickens and ducks (Nickel *et al.*1977), 17 in ibies (Kaneko *et al.* 2009), 13 in penguins (Guinard *et al.* 2010), 17 to 18 in red crowned cranes and hooded cranes (Hiraga *et al.* 2014), 14 in cattle egret (Rezk, 2015). In blue-and-yellow macaw and mute swan 10 and 23, respectively (Bohmer *et al.* 2019), 13 in short-necked cinereous vulture and 15 in long-necked griffon vulture (Houston, 1987). Bellairs and Jenkins (1960) stated that the number of cervical vertebrae directly related to the degree of neck curvature rather than its length.

Atlas

It was the smallest of all the cervical vertebrae which was ring like shape. The neural spine, hypapophyses, body, transverse process and foramen transversarium were absent. The dorsal arch was thin and delicate. The ventral arch anteriorly presented an articular socket for the single occipital condyle to associate with skull and posteriorly a deep depression for the odontoid process for axis. The atlas showed a ball-and-socket joint and a pivot joint with the axis in barn owl (Krings *et al.* 2014).

Axis

It was quite larger than the atlas. It had a well-developed neural spine with the dense small triangular with a blunt apex. The odontoid process arises vertically from the posterior margin of the upper surface of the body. Transverse process did not show foramen transversarium. Skull and atlas gets mobility over the axis.

All cervical vertebrae except the atlas had a vertebral body and arch. Most of the cervical vertebral joints were saddle shaped, which permit sliding at close distance while preventing disarticulation of vertebral articular faces during neck movement. The neural spine of the 2nd, 3rd, 4th cervical vertebrae were of equal height. From 4th cervical vertebrae onwards, the height of neural spine declined and as it passed toward the thoracic region this process became less and less prominent. From the C11th neural spine began to appear again and quite evident in the 13th cervical vertebra. The C14th was quadrate in shape. The hypapophyses/cristae ventrales was well developed and projected from the ventral surface of body in C3rd and C 4th in the form of a sharp crest. Thereafter, it was absent from the 5th to 10th and from the 11th to 13th it was a sharp bony plate. The hypapophyses of the C14th was characteristic feature in Indian eagle owl which showed trifid hypapophyses.

The transverse processes showed caudally directed bony spicules called the styloid process which made its appearance in the third cervical vertebrae. From the C4th to C13th well developed styloid processes (pleurapophysis) was noticed. The transverse processes formed by the union of parapophysis and diapophysis was situated under the prezygapophyses. In the 14th cervical vertebrae, transverse processes was a thick, very broad bony plate and numerous pneumatic foramen were observed underneath the transverse process. The styloid processes (pleurapophysis) was observed as bony spicules increased in thickness from slender blunt to sharp pointed ends. Well-developed foramen transversarium was noticed in the roof of transverse processes just beneath the prezygapophyses. All the cervical vertebrae, except atlas and axis had two canals of the foramen transversarium. The neural canal showed transverse ellipse shape from atlas to the 7th vertebra, the ellipse canal gradually changes to circle in shape. Atlas had maximum capacity throughout the canal and this gradually decreases in subsequent vertebra and reaches maximum capacity toward the last two cervical vertebrae. Several pneumatic foramina perforate each cervical vertebra at various points, except in the axis and atlas. The horizontal lamina of 3rd cervical vertebrae was nearly straight, while that of the 4th onwards it showed indentation deepened and were “V” shaped until the C10th. The postzygapophyses was nearly straight, while that of the C4th showed a slight indentation. The indentation deepened and the V-like notch in lacuna interzygapophysialis showed between postzygapophyses from C5th to C10th.

The zygophyseal protrusion was small in C1 and C2 while in 3rd and 4th it was short and from 5th onwards the size

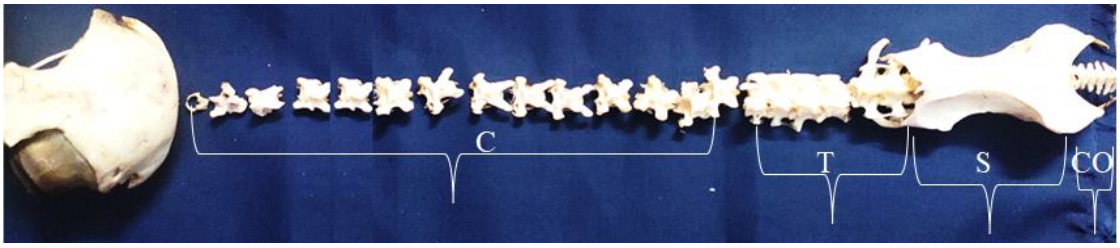

Fig 1: Vertebral Column of Indian eagle owl showing (a) Cervical (b) Thoracic (c) Lumbar and Sacral fused to form Synsacrum which articulates with Pelvic Girdle and (d) Coccygeal vertebrae.

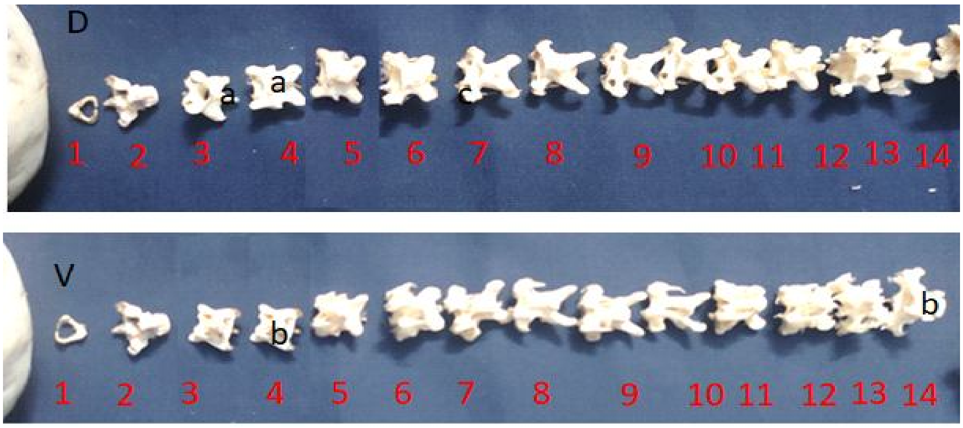

Fig 2: Dorsal and ventral view of cervical vertebrae showing (a) Neural Spine, (b) Hypapophyses, (c) Transverse Processes.

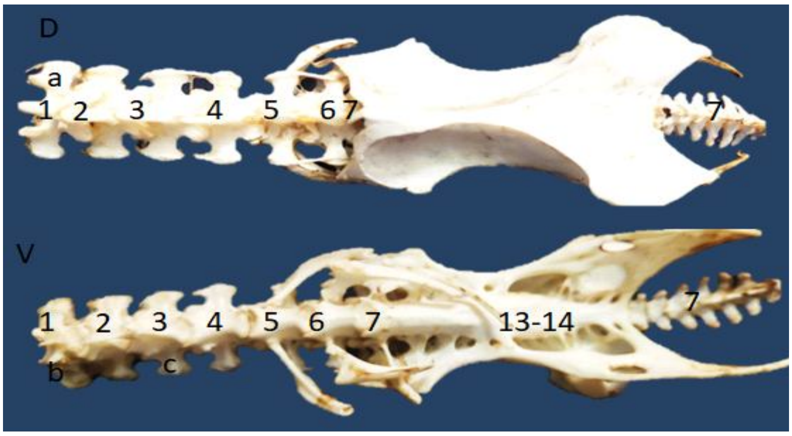

Fig 3: Dorsal and ventral view of thoracic, synsacrum and coccygeal vertebrae showing (a) Neural spine (b) Hypapophyses (c) Transverse processes.

further grown until the 9th, then onwards it decrease in size till to 14th which was in agreement with the finding made in barnowl (Krings *et al.* 2014). The measurement on zygophyseal protrusion of C1st to C10th were as follows 1.04±0.1 mm, 1.73±0.15 mm, 1.79±0.05 mm, 2.06±0.1 mm, 3.02±0.2 mm, 4.32±0.15 mm, 4.64±0.18 mm, 4.94±0.21 mm, 3.12±0.14 mm, 2.13±0.18 mm, respectively. The last three cervical vertebrae were 1.73±0.14 mm and in C14th was 2.1±0.16 mm. There was a gradual increase in the width of the bodies of vertebrae from cranial to caudal series.

Thoracic vertebrae

There are 7 thoracic vertebrae (Fig 3) in Indian eagle owl, while in cattle egret 10 in number (Rezk, 2015), 7 in fowls and pigeons, 9 in ducks and geese (Nickel *et al.* 1977). The first thoracic vertebrae anteriorly articulates with last cervical vertebrae and the last thoracic posteriorly with the first lumbar vertebrae. The 1st to 6th were free and the last thoracic vertebrae was fused with the lumbo sacrum but however, in fowl and pigeon the 2nd to 5th vertebrae were fused into a bony column. Tahon *et al.* (2013) mentioned in chicken that 2nd to 5th were fused together forming the notarium. Moreover in chicken the last cervical and first three thoracic vertebrae were fused in the thoracic region to form notarium (Hogg, 1982; Mclelland, 1990). In the present study the last cervical and thoracic vertebrae were free. The last thoracic vertebrae was the smallest, the second and third was the largest thoracic vertebrae. The fused vertebrae of last thoracic had a pair of floating ribs. The neural spine of the thoracic vertebrae was flattened and compressed by median crest and had similar height in all the thoracic vertebrae. All the thoracic vertebrae showed same body width from cranial to caudal series.

The hypapophyses was well developed in the first three thoracic vertebrae. The hypapophyses of the first two thoracic vertebrae were trifid in nature, specific feature to Indian eagle owl. Hypapophyses of the 3rd thoracic vertebrae was longer and pointed but in last three thoracic vertebrae the hypapophyses was absent. Transverse processes were broader plate like and projected from the lateral surface of the vertebral arch. A thin bony plate connected the adjacent transverse processes and transformed the adjacent notches into a large foramen for the passage of the dorsal division of thoracic spinal nerves. The lateral surface of the vertebral body pair each side of the centrum presented a facet for articulation with the head rib parapophysis. The lateral borders of transverse processes bearded for articulation with tuberculum costale diapophysis with its corresponding rib. Immediately above these facets, on either side a group of pneumatic foramina of various sizes and shapes were noticed. The neural canal was nearly cylindrical in the dorsal region and its calibre gets thinner at the sacral extremity.

Synsacrum

Synsacrum was a fused bony part of 13-14 lumbar and sacral vertebrae which were fused anteriorly with the last thoracic vertebra. There was a great variation in number of vertebrae forming the synsacrum in chickens (15-16) as described by Tahon *et al.* (2013), 15-17 in Red-crowned cranes and 14-16 in hooded cranes was reported by Hiraga *et al.* (2014). However, Hogg (1982) recorded that the lumbosacral region in chicken composed of 14-16 elements and the last thoracic vertebra in almost all birds were involved in synsacrum. Synsacrum had connections with the medial surface of ilium through their fused spine and transverse processes. All fused lumbar vertebrae had free transverse processess which were applied against ilium. The sacral vertebrae lie behind the lumbar and fused with their transverse processes thereby formed a lamina which was connected laterally to the post acetabular part of the ilium. The largest foramina exit for the roots of sacral nerve which generally seen in fifth vertebra after they decreased in size. The transverse processes of the five sacral vertebras are thrown out against the medial surfaces of the ilium to which they are firmly attached and act as a support to hold the engaged bones together. Between the fused transverse processes several foramina were noticed dorsally. The body was compressed from side to side to such an extent to cause them to appear wedge-shaped after that broaden and become compressed vertically.

Coccygeal vertebrae

The caudal vertebrae consisted of seven free coccygeal vertebrae and the pygostyle together formed bony part of tail region. Co7 in Red-crowned cranes and Co6 to 8 in

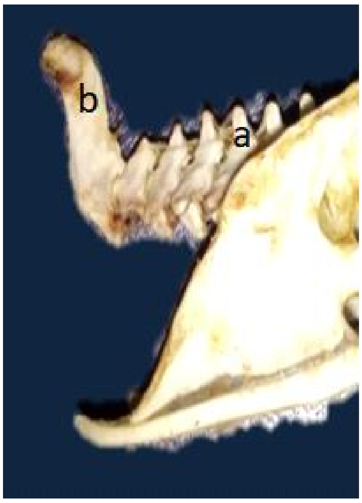

Fig 4: Lateral view of coccygeal Vertebrae showing (a) Neural spine and (b) Pygostyle.

Hooded cranes was reported by Hiraga *et al.* (2014). Co5 in cattle egret Rezk (2015), Nickel *et al.* (1977) and Tahon *et al.* (2013) in chicken. They were all freely movable upon one another and the coccygeal vertebrae articulated with the last sacral vertebra. The articular facets vary in shape. The first coccygeal vertebrae was long transversely, with a double convexity and from second to last had uniform shape which was concave in nature. All the seven coccygeal vertebrae presented well developed bifurcated neural spine which facilitates for increased muscular attachment. The hypapophyses was noticed from 3rd to 7th coccygeal vertebrae. It appeared in the 3rd coccygeal vertebra and it was very small cranially with directed bony plate, while in 4th to 7th coccygeal vertebrae it was well developed and showed forward inclination. Transverse processess were observed as slightly cylindrical in shape with 1st, 2nd , 3rd and 4th were directed downwards and outwards, while 5th onwards directed forward with 4th and 5th transverse process largest of all. But in the 7th coccygeal vertebrae, the transverse process was very small. The last segment of coccygeal vertebrae found with absence of body, neural spine and shaped like plough-share by plate called pygostyle (Fig 4). It was large in size formed by fusion of variable number of individual caudal vertebrae. It supports to the oil gland and rectrices feather provide attachment to the muscle. The neural canal gradually diminishes to terminate into a blind conical socket within pygostyle.

CONCLUSION

The vertebral column of in Indian eagle owl had total 42 vertebrae, with 14 cervical vertebrae, 7 thoracic, 13-14 lumbar and sacral vertebrae are fused giving rigidity which aids in flight, 7 coccygeal. The neural canal had maximum capacity at the cranial region then gradually diminishes as it progress towards the caudal region and gets terminated into a blind conical socket within pygostyle. The vertebral column had characteristics features of hypapophyses, transverse process, pneumatic foramen and neural spine which enable the owl to adapt for head rotation and various task involving vertebrae. The zygophyseal protrusion of cervical vertebra showed characteristics feature with gradual increase in size reaching maximum at C8 and then on decrease in length. The transverses process of 14th cervical vertebra was well distinguished from rest of other transverses process of cervical vertebra. The hypapophyses of the 14th cervical vertebra and first two thoracic vertebrae were trifid in nature specific feature seen in Indian eagle owl.

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