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GROSS AND MORPHOMETRICAL STUDIES ON DIFFERENT CERVICAL VERTEBRAE IN DROMEDARY CAMELS

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ABSTRACT

The gross anatomical and morphometrical observations of cervical vertebrae of dromedary camels showed many differential features than other domestic animals. The cervical region of camel was made up of seven typical and atypical irregular bones. Longer neck region contributed 46.73% in respect to whole vertebral column. The foramen transversarium was observed in whole cervicals except C7. The length of neural canal was maximum in C2 and minimum in C7. The height of neural canal was greatest in C1 and C7 and least in C2. The Mid-cervical having similar neural canal length but width increased progressively. The atlas having lowest TCV (8.42%) and TVC (3.93%), while C2 contributed highest in TCV (17.78%) and TVC (8.31%).

Key words: Atlas, axis, cervical vertebrae, dromedary camel, foramen transversarium, morphology, morphometry

Most of mammals have seven cervical vertebrae (neck bones), including camel, giraffes, bats, whales, and humans. However, long neck in camel and giraffe is due to more length of vertebrae. The necks of two large and long-necked recent mammals, *Giraffa camelopardalis* and Camelus sp., were examined for the reconstruction of the habitual posture of long necked terrestrial vertebrates (Christian, 2002). The special anatomical characters of cervical vertebrae enables the long necked camel to have a better visibility through required movements of the neck and it also helps them to feed on trees and bushes. Some researchers have studied the cervical vertebrae of camels, previously (Sharma *et al*, 2013; Smuts and Bezuidenhout, 1987; Martini *et al*, 2018). Present research was, therefore, aimed for a detailed gross and morphometrical studies of cervical vertebrae in dromedary camels.

Materials and Methods

The cadavers of 6 camels were processed after proper maceration, cleaning, drying and disinfection with the help of hot air oven and all cervical vertebrae viz. C1 to C7 from every camel were collected. Gross and morphometrical observations, i.e. length, width and thickness were recorded with the help of Vernier caliper, metre scale and thread. The mean and standard error of each measurement were calculated by standard method and analysed.

Results and Discussion

The neck in camel was observed quite longer in comparison with other ungulates. The neck has seven cervical vertebrae along with typical and atypical types. In present study, cervical vertebrae has shown 46.73% of contribution in the entire vertebral column whereas Badlangana *et al* (2009) found it as 45-54% in giraffe, 40% in camel, 44% in lama and 27% in sheep and goat. Sharma *et al* (2013) found the length of camel vertebrae about 28% of total dorsal axial length of camel. The C2-C6 vertebrae were presented with the foramen transversarium which was located at the lateral wall of neural canal. Similar types of observations were reported by Badlangana *et al* (2009) in camel and lama and Torres *et al* (1986) in camelids. However, in other domestic animals and giraffe it penetrates the transverse process, (Badlangana *et al,* 2009 and Ghosh, 2018). The foramen transversarium in C7 was not found in present study, but it was found in giraffe (Badlangana *et al,* 2009). The C2 had a maximum and the C7 had a minimum neural canal length. But, the C1 had the second minimum neural canal length among all the cervical vertebrae, nevertheless C1 has shown minimum neural canal length among atypical and C7 has shown minimum among typical of the cervical vertebrae. The maximum height of neural canal was found at the either side of cervical vertebrae viz. C1 and

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C7. Among which the C1 was maximum than C7, along with the minimum height of neural canal was observed at C2 in animals of present study. These observations were very similar with the findings mentioned by Badlangana *et al* (2009) in giraffe, camel and lama. The similar length of neural canal was observed at C3-C5 vertebrae but the width was increasing progressively. The C6 was found shorter in length and largest in width, while C7 was shortest in length among all typical cervical vertebrae in present study, which was in accordance with observations of Grossman (1960) and Smuts and Bezuidenhout (1987) in dromedary (Table 1).

Atlas vertebrae

The maximum length (104.89±0.84 mm) and maximum width (64.41±1.28 mm) observed in atlas in present study was similar to those reported by Sharma *et al* (2013) and Grossman (1960) in camel. The height of neural canal (43.56±0.23 mm) was the maximum in all cervical cases while the length of the neural canal (46.89±0.81 mm) was less among all of the cervical vertebrae except seventh cervical. The contribution of atlas was lowest in length of total cervical vertebrae (TCV) and total vertebral column (TVC), which was calculated as on 8.42% and 3.93%, respectively. The results were in accordance with Torres *et al* (1986) in camelids. The neural ring was elliptical anteriorly and round shaped posteriorly. On the anterior to fovea dentis a rough articulating area was also noticed at floor, possibly to get the sound grip of atlas and axis and balancing of the skull during movement. The intervertebral foramen was present at the lateral wall of neural ring with an anterior and posterior opening. Anterior and posterior adjacent openings were located at neural canal, however, the anterior opening was at its lateral wall and the posterior was found at the mid lateral area. These findings were in accordance with Torres *et al* (1986) seen in camelids. Researchers found that anterior openings had a common passage with intervertebral canal in camels (Smuts and Bezuidenhout, 1987). The cranial opening was larger and the caudal one was smaller, situated in the mid-lateral of the neural ring. The atlas articulated at anterior end with occipital condyle of skull and its posterior end articulated with anterior of axis. Both the division of atlas viz. anterio-dorsoal and anterio-ventral received the occipital condyle and formed atlanto-occipital joint. These findings were in accordance with Ghosh (2018) in domestic animals. The anterio-dorsal articular area had a division resulted into two parts by a large 'C' shaped notch, however, anterio-ventral area had the large 'C' shaped condyles that were forming two parts with sloping downward. Present findings were in accordance to Smuts and Bezuidenhout (1987) in dromedary. Torres *et al* (1986) did not find any notch/groove found between anterio-dorsal articulation area in camelids. The thickness of anterio-dorsal plate, anterio-ventral plate and anterio-lateral thickness was 1.57±0.10 mm, 23.49±1.39 mm and 5.75±0.41 mm, respectively. The metrical findings on anterio-circular diameter of the atlas were 136.36±2.21 mm, which was comparable with the findings of Sharma *et al* (2013). The posterio-dorsal part of bone was observed as a very thin bony plate, while the posterio-ventral part was very thick and these had metrical measurement of 1.6±0.5 mm and 19.13±1.7 mm, respectively. The posterio-lateral thickness was 1.43±0.1 mm. The posterio-circular diameter was 261.61±3.59 mm. The posterior part which receives the anterior articular area of the axis was a smooth area which had a lateral process that curved backward and upward towards the odontoid

Table 1. Morphometrical observations of cervical vertebrae of camels.

Bone		Atlas		Axis		3rd Cervical		4th Cervical		5th Cervical		6th Cervical		7th Cervical	
		Mean ± SE		Mean ± SE		Mean ± SE		Mean ± SE		Mean ± SE		Mean ± SE		Mean ± SE	
Max. length (mm)		104.89±0.84		221.47± 0.59		196.62± 0.74		193.83±0.61		190.57±0.91		175.55±0.66		162.65±0.57	
Max. width (mm)		64.41±1.28		90.64±0.79		97.54±0.65		118.21±0.59		116.08±0.05		177.54±1.25		135.11±0.93	
Neural Canal (mm)	Min. height	29.07±0.71		21.74±0.38		22.50±0.24		24.05±0.68		26.11±0.08		28.14± 0.21		32±0.17	
	Max. height	43.56±0.23		24.26±0.18		25.38±0.42		29.17±0.73		29.51±0.62		31.13±0.51		33.61±0.48	
	Length from inside	46.89±0.81		125.12±0.60		112.11±1.23		101.78±0.75		92.77±0.90		76.21±1.10		41.71±0.43	
% Contribution		TCV*	TVC**	TCV*	TVC**	TCV*	TVC**	TCV*	TVC**	TCV*	TVC**	TCV*	TVC**	TCV*	TVC**
Length		8.42	3.93	17.78	8.31	15.78	7.37	15.56	7.27	15.29	7.15	14.09	6.58	13.05	6.10

* TCV- Total Cervical vertebrae ** TVC- Total Vertebral Column

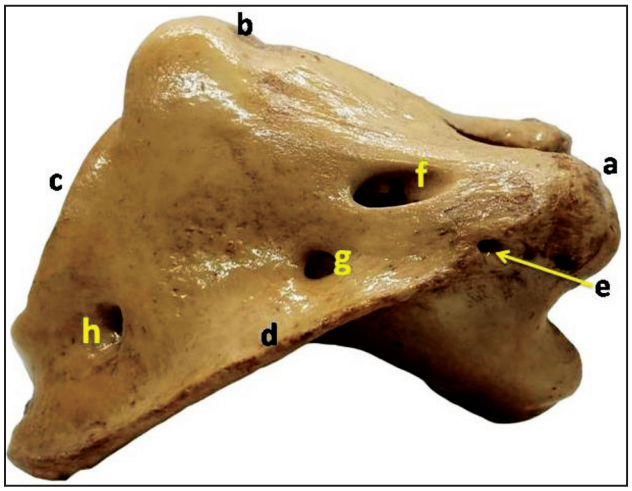

Fig 1. Lateral view of atlas of camel showing (a) Anterior surface, (b) Dorsal surface, (c) Posterior surface, (d) Wing, (e) Accessory alar foramen, (f) Intervertebral canal, (g) Foramen alar, (h) Foramen transversarium.

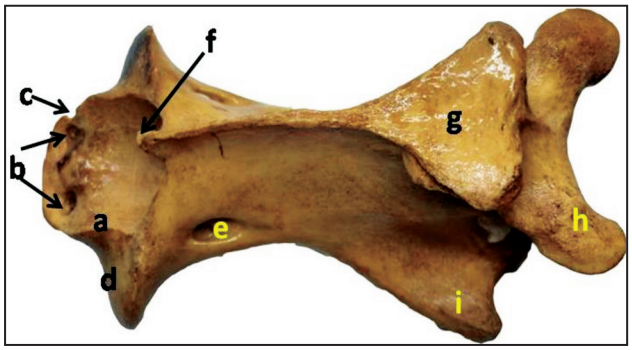

Fig 2. Dorsal view of axis (C2) of camel showing (a) Dens, (b) Lateral depressions of dens, (c) Lateral notch of dens, (d) Anterior articulating surface, (e) Dorsal opening of intervertebral foramen, (g) Bifid dorsal spine, (h) Posterior articulating facets, (i) Wings.

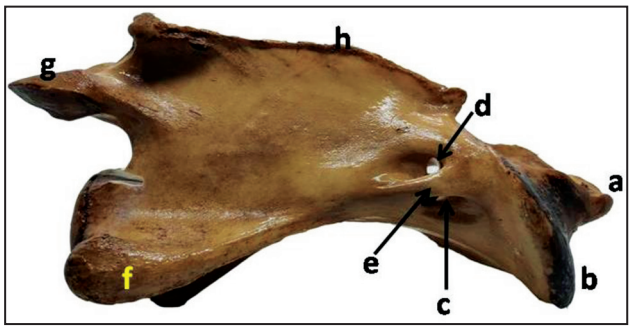

Fig 3. Lateral view of axis (C2) of camel showing (a) Dens, (b) Anterior articulating surface, (c) Ventral opening of intervertebral foramen, (d) Dorsal opening of intervertebral foramen, (e) Bony plate, (f) Wing, (g) Anterior articulating facets, (h) Dorsal spine.

process of axis (C2) vertebrae. These findings were similar to these seen by Torres *et al* (1986) in camelids. The dorsal surface of wings had several perforations after foramen and canals. The smooth dorsal part was

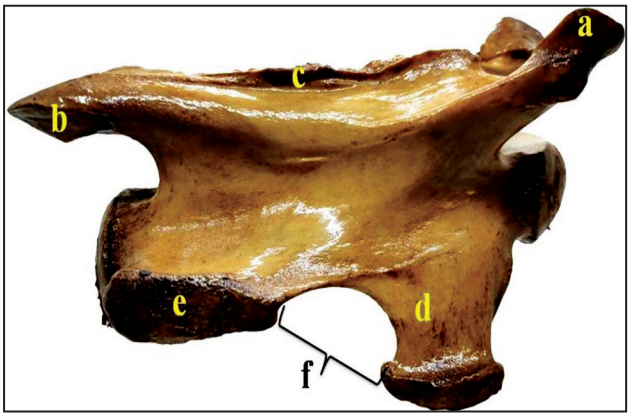

Fig 4. Lateral view of C3 of camel showing (a) Anterior articulating facets, (b) Posterior articulating facets, (c) Dorsal spine (d) Ventral transverse process, (e) Dorsal transverse process, (f) Half moon shaped structure.

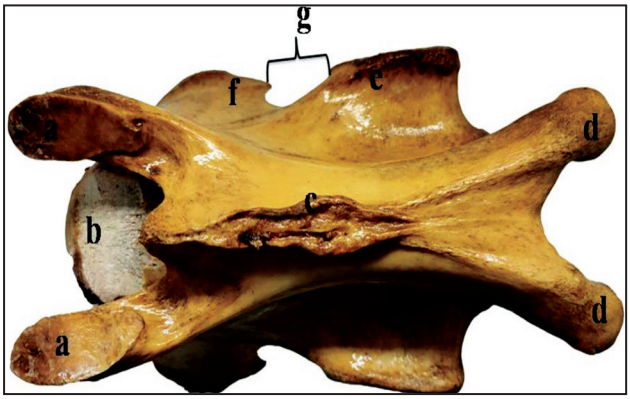

Fig 5. Dorsal view of C4 of camel showing (a) Anterior articulating facets, (b) Body, (c) Dorsal spine, (d) Posterior articulating facets, (e) Dorsal transverse process, (f) Ventral transverse process, (g) Half moon shaped structure.

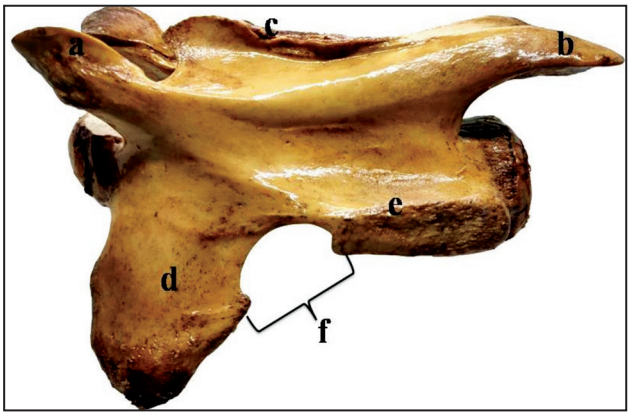

Fig 6. Lateral view of C4 of camel showing (a) Anterior articulating facets, (b) Posterior articulating facets, (c) Dorsal spine, (d) Ventral transverse process, (e) Dorsal transverse process, (f) Half moon shaped structure.

sloping laterally and posteriorly. The thin and convex wings had rough and curved borders. Present results

Fig 7. Dorsal view of C4 of camel showing (a) Anterior articulating facets, (b) Body, (c) Dorsal spine, (d) Posterior articulating facets, (e) Dorsal transverse process, (f) Ventral transverse process.

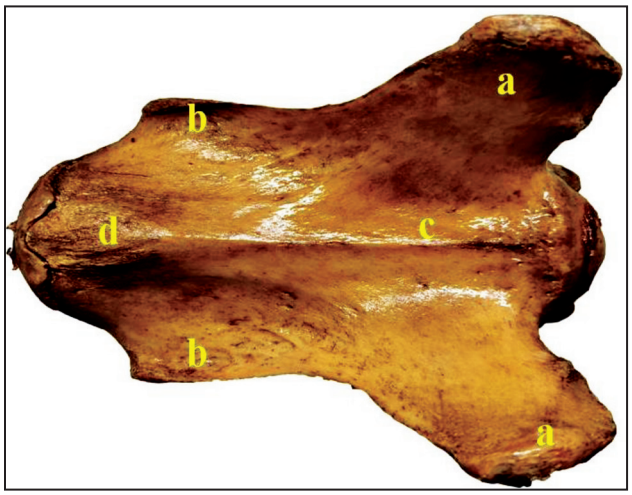

Fig 8. Ventral view of C5 of camel showing (a) Ventral transverse process, (b) Dorsal transverse process, (c) Ventral spine, (d) Ventral tubercle.

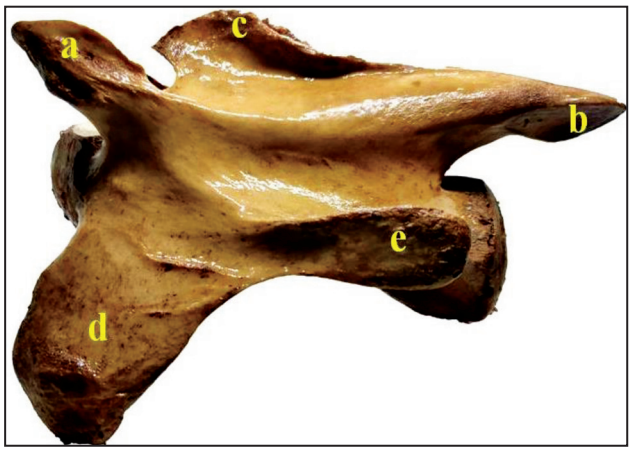

Fig 9. Lateral view of C5 of camel showing (a) Anterior articulating facets, (b) Posterior articulating facets, (c) Dorsal spine, (d) Ventral transverse process, (e) Dorsal transverse process.

Fig 10. Dorsal view of C6 of camel showing (a) Anterior articulating facets, (b) Body, (c) Dorsal spine, (d) Posterior articulating facets.

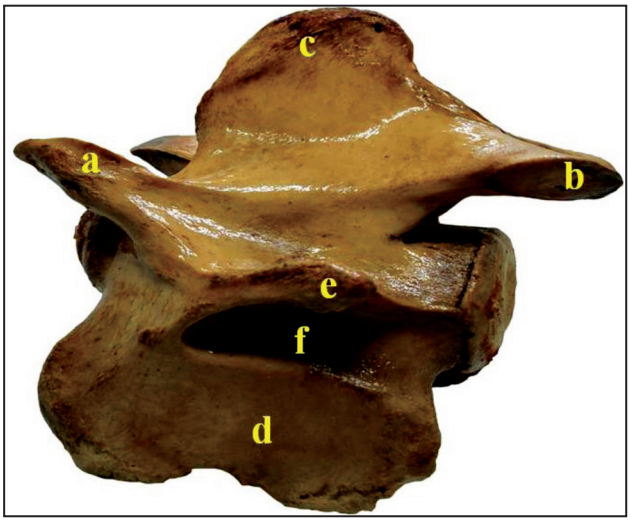

Fig 11. Lateral view of C6 of camel showing (a) Anterior articulating facets, (b) Posterior articulating facets, (c) Dorsal spine, (d) Ventral transverse process, (e) Dorsal transverse process, (f) Shallow fossa.

Fig 12. Lateral view of C7 of camel showing (a) Anterior articulating facets, (b) Posterior articulating facets, (c) Dorsal spine, (d) Ventral transverse process, (e) Dorsal transverse process, (f) Anterior part of body, (g) Costal facets.

were in accordance with those of Sharma *et al* (2013) in camels. The posterior part of wings ended in a tubercle which were similar to those seen by Torres *et al* (1986) in camelids.

Ventral surfaces of wings were concave with few rough lines on it. The large depression seen was identified as the fossa atlantis and a large ventral foramen was present near by which was the opening for all four foramen present on the wings of atlas which were in accordance with Grossman (1960). These findings were also in accordance with Ghosh (2018) in domestic animals but Smuts and Bezuidenhout (1987) found double ventral foramen in dromedary. Three foramen and canals were present at anterior part of the wings, while one was at the posterior part. The anterior most foramen was the first that was located on wings with a very small opening, which identified as the accessory alar foramen. The second was the intervertebral larger foramen which was situated towards medial aspect of the wings that had canal connectivity with smaller intervertebral foramen situated at antero-lateral neural canal. The third was the alar foramen which was situated about mid-lateral onto the wings of atlas and it was located just behind the larger intervertebral foramen. Badlangana *et al* (2009) found that dorso-posterior surface had a sloping towards the anterior in giraffe. The dorsal surface of atlas had a rough thin linear abbression initiating from a posteriorly located rough area that reached up to the anterio-dorsal 'C' shaped structure and also the said thin linear abbressions helped to have the two equal halves of dorsal surface. A small 'V' shaped notch was located at anterio-ventral surface which gave the smooth line that traveled up to posterio-ventral surface. The ventral arch was present at the either side lateral to smooth line forming a rough area. Ventral tubercle was observed and these findings were in accordance with these of Torres *et al* (1986) in camelids, but they reported about presence of ventral tubercle. The posterio-ventral portion had slope towards anterio-ventral portion (Fig 1 & Table 1).

Martini *et al* (2018) found the size of the ventral foramen (single opening in the atlantid fossa) as best diagnostic character of atlas, which is so large in Bactrian camels that there is no interspecific over-lap of its diameter in the studied samples. Differences were found in the dorsal foramina; in dromedaries, the cranial (alar) foramina were more distant from each other, had the same distance from the cranial border (at4°), and a greater distance from the caudal (transversal) foramina, suggesting that the last can be closer to the caudal border. In Bactrian camels the vertebral channel was normally higher: this can be seen in the taller cranial and caudal articular opening, and the greater diagonal height of the cranial and caudal articular cavities. All previous analyses (Lesbre, 1903; Wapnish, 1984; Steiger,1990) recognised the diagnostic importance of the ventral foramen in the atlantal fossa. Steiger (1990) suggested that the wings were caudally more developed in Bactrian camels, but we found that these were barely longer in dromedaries. Lesbre (1903) observed that the transversal foramina were closer to the caudal border in dromedaries. The vertebral channel was found dorsoventrally taller in the Bactrian camel.

Axis vertebra (C2)

The C2 was found longest (221.47±0.59 mm) and narrowest (90.64±0.79 mm) of the cervical vertebrae. The smooth, less developed ventral process had a tubercle at its posterior part. The anterior part of the process was in the form of a line that divided the ventral surface into two halves. The odontoid process was tongue like. The contribution of C2 vertebrae was highest in forming the length of total cervical TCV and TVC, which was 17.78% and 8.31%, respectively (Table 1). Intervertebral foramen was located at one-third from anterio-lateral aspect and just behind the anterior opening of the neural canal. It had two large oval shaped openings i.e. dorsal and ventral which were separated by a thin bony plate. The foramen transversarium was observed at anterio-lateral aspect that showed the common opening with intervertebral foramen and connectivity upto the opening at neural ring. The anterior end of the body appeared to be modified in forming the attachment with atlas for which a large 'C'shaped anterior articular surface was there, to form an atlanto-axial joint. The broad body was observed for the articulation along with the rounded neural ring. The dorsal spine was narrow at anterior and middle part while its posterior part was broad, bifurcated, flat, smooth dorsally and rough laterally. Anterior part of the spine was pointed and hanged over the neural ring (Fig 2 & 3). Martini *et al* (2018) found that the axis had classical morphometrical characters, i.e. the common opening of the lateral and the transversal foramina was covered by a bony bridge in dromedaries, but not in Bactrian camels. The bridge was incompletely developed (not closed) in two dromedaries and one Bactrian camel with initial development. Bactrian camels had a greater maximal breadth but at the same time a smaller minimal breadth. The length of both arch and body was greater in dromedaries. Both

Lesbre (1903) and Steiger (1990) saw the presence of a divided lateral foramen in the axis as a reliable distinction.

3rd, 4th and 5th Cervical Vertebrae (C3, C4 and C5)

In their serial placement the bodies of C3, C4 and C5 shorter and wider progressively camel (Fahmy *et al,* 1996). The length and width of C3, C4 and C5 vertebrae mid cervical region plays the balancing role for the neck region of animal. C3 has maximum contribution and C5 was the minimum to the length of vertebrae of mid cervical region.

The supraspinous process which was short and centrally tuberous in the C3, gradually increased in height and length to the C6 with backward inclination. These findings were in accordance with Sharma *et al* (2013) and Fahmy *et al* (1996) in camel. The anterior articulating facets were increased in size, surface area and became less oblique in successive vertebrae. The transverse processes were divided into upper tubercle portion, which projected at right angles, and lower plate-like portion directed outwards, downwards and foreward. The size of the ventral transverse process was increased in successive vertebrae (Sharma *et al,* 2013). In C3 and C4 the dorsal and ventral transverse processes were divided by a half moon shaped structure, but it was absent in C5. The back of this process was pierced by two openings of transverse canals. The anterior opening was present at anterio-lateral aspect of neural canal just below and medial to the anterior articulating facets. The posterior opening was present lateral at two third from the posterior surface of the neural ring. Which were in accordance with Grossman (1960) in camel. The size of foramen transversarium was progressively increased in successive vertebrae. Sharma *et al* (2013) found that it was small and opened into the mid-lateral wall of neural canal. A well-defined infraspinous process was seen on body ventrally which, increased in length and angle of descent. These findings were in accordance with Sharma *et al* (2013) and Grossman (1960) in camel (Fig 4, 5, 6, 7, 8 and 9).

Sixth cervical vertebra (C6)

The supraspinous process of this vertebra was well developed while the infraspinous process was absent. The slope of the spine of the supraspinous process was sharp towards the anterior border. Similar observation were made by Fahmy *et al* (1996); Sharma *et al* (2013) in camel. Length wise C6 was quite similar with C7 but its width was the maximum among all the cervical vertebrae. The anterior opening of foramen transversarium was very large and opened at anterio-lateral aspect of the neural ring. It was located just below the anterior oblique articulating process and dorso-lateral asped of the body. Similar observation were made by Grossman (1960) in camel. Sharma *et al* (2013) were reported that it pierced the anterior part of transverse process in camel. The Neural ring was larger. The Transverse process was divided into dorsal and ventral parts. The dorsal part was situated at posterior aspect while the ventral part was at anterior aspect. The dorsal part was smaller than the similar part of preceding cervical vertebra which was situated dorsally to the ventral transverse process and formed a tubercle at its end. The ventral part of the transverse process was the largest among all the cervical. It covered the ventral part of the body of C6. The ventral part of the transverse process was directed downward and outward in position. There was a shallow fossa present at the lateral surface in between the dorsal and ventral transverse process. Similar observations has were made by with Sharma *et al* (2013) in camel (Fig 10 and 11).

Seventh cervical vertebrae (C7)

C7 shared the characters of both cervical and thoracic segments. The supraspinous process was flat, thin and highest in the length and inclined backward in contrast to ox where it inclined forward. The result were in accordance with Sharma *et al* (2013) in camels and Torres *et al* (1986) in Camelids. Tubercle was present at the anterior and posterior end of the ventral process. The anterior part of the body was short, convex, oval and larger in dimension than preceding cervical. The posterior part was concave from middle and at either side of the body there were two costal facets for the attachment of the first pair of ribs. The transverse process was divided into dorsal and ventral part. The dorsal part was directed backward and outward while the ventral part was directed downward and forward in position. These results were in accordance with Sharma *et al* (2013) in camel. It was larger than all cervicals but without foramen transversarium. Similar results were reported by Sharma *et al* (2013) in camel, and Ghosh (2018) in domestic animals. However, it contradicted the report of Badlangana *et al* (2009) in giraffe where foramen transversarium was present. Torres *et al* (1986) reported that foramen transversarium may or may not be present in C7 of Camelids (Fig 12).

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