

Age-Related Morphological and Morphometrical Changes in the Goat Brain: A Gross Anatomical Study

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Received: 05 June 2025 ; Accepted: 28 June 2025

ABSTRACT

The present study was conducted on the brain of the black Bengal goat irrespective of sex. Whole experiment was divided into two groups i.e Group-I comprise of six young goats (6 to 8 months of age) and Group- II comprise of six adult goats (above 8 months of age). The gross biometrical observation of cerebrum and cerebellum were recorded. The cerebrum was the largest part of the whole brain in both age groups of Black Bengal goat. Its shape varied from triangular to oval in outline. The cerebellum was the largest part of the rhombencephalon situated behind the cerebrum and dorsal to the pons and medulla oblongata. The cerebellum was oval with wider dimension along transverse axis. In mid- sagittal section of cerebellum, ten distinct lobules were observed in both the age groups of goats. The length as well as width of cerebrum was found to be increased with the advancement of age from group I to group II, but no significant differences were observed in length and width of cerebrum of goat from Group I to II.

Key words: Black Bengal Goat; Cerebellum; Cerebrum; Morphology; Morphometry

INTRODUCTION

The central nervous system, particularly the brain, undergoes significant morphological and functional changes throughout the life span of an animal. In domestic ruminants like goats (*Capra hircus*), understanding the gross anatomical changes in the brain across different age groups is critical for both clinical neuroanatomy and developmental biology. Despite the widespread use of goats in veterinary education, research, and as animal models in neuroscience, detailed studies on age-related gross anatomical brain changes remain scarce.

During early postnatal life, the brain continues to mature, showing increases in size, sulcation, and complexity of gyri, especially in the cerebral hemispheres. These developmental changes are associated with the acquisition of motor coordination, sensory integration, and behavioural maturity (Kumar *et al.*, 2012). As the goat matures into adult, the brain reaches structural stability, although certain subtle morphological changes may still occur due to physiological aging or

environmental adaptation (Moss, 1978).

Morphometric studies in other domestic animals, including sheep and cattle, have demonstrated measurable changes in brain dimensions and structure with age (Fitzgerald & Crossman, 2007). Documenting such changes in goats may contribute to a better understanding of developmental neurobiology in small ruminants and enhance their utility in translational research.

This study aims to investigate and document the age-related morphological changes in the gross anatomy of the goat brain, comparing key anatomical features between young (neonatal and juvenile) and adult individuals. By establishing a baseline for normal developmental variations, the findings will offer insights applicable to veterinary neuroanatomy, surgical approaches, and neuropathological diagnostics in goats.

MATERIAL AND METHODS

The experiment was carried out at the Department of Veterinary Anatomy, Bihar Veterinary College, Patna. For this research, the heads of goat were collected immediately after slaughter from the local market of Patna. The study was designed to

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investigate the gross anatomical differences in the brain—specifically the cerebrum and cerebellum of young and adult goats, irrespective of sex. The entire experiment was divided into two groups: Group I, consisting of six young goats aged between 4 to 6 months, and Group II, comprising six adult goats aged above 8 months.

After procurement, the heads were subjected to longitudinal craniotomy for careful expose and extraction of intact brain.

For gross anatomical examination, the brain samples were first rinsed thoroughly in normal saline to remove blood and debris. Gross observations were made and photographs were taken prior to morphometric analysis. Measurements were performed using a digital slide calliper and a measuring scale. The gross parameters recorded were length and width of the whole brain, length and width of the cerebrum, and length and width of the cerebellum, in centimeters.

RESULTS AND DISCUSSIONS

Whole Brain

The brain of black Bengal goat of each group was segmented mainly into cerebrum, cerebellum and medulla oblongata as earlier reported by Rashouli and Gholami (2020) in male and female mongoose. External surface of the entire brain was covered with three layers of the meninges, the dura mater, the arachnoid layer, and the piamater. The dura mater was the tough outermost layer, the middle arachnoid layer and pia mater, the inner layer, are closely invested over the brain. The cerebral hemisphere and cerebellum were visible from dorsal view of the brain, whereas, well developed olfactory lobe, cerebrum, optic chiasma (criss-cross of optic nerves), piriform lobe, cerebral peduncle, pons and medulla oblongata were clearly observable on ventral surface of the brain in both age group of goats. (Fig.1). Present findings about the parts of brain and protective covering of brain are in accordance with report of Rao (2024) in gaddi goat and adult sheep, (Beulah 2021). Kavoi and Jameela (2011) reported that the olfactory bulb was well developed in dog, goat and human beings in support of present findings.

The mean length of whole brain of Black Bengal goat in Group I was 7.82 ± 0.40 cm (ranged 5.95 to 9.84 cm) and in group II 8.26 ± 0.31 cm (ranged 6.87 to 10.05cm). The average width of whole brain was

5.27 ± 0.41 cm which ranged from 3.29 cm to 7.01cm and 5.98 ± 0.36 cm that varied from 4.09 to 7.17 cm in group I and II respectively (Figs. 2&3 and Table.1). Olopade *et al.* (2005) reported that in West African dwarf sheep the mean brain length and depth were 7.48cm and 4.17cm respectively in support of present findings. In Sahel goats the mean length of brain was 9.38 cm (Olopade *et al.* 2007).

In the present study the length as well as width of whole brain was found to be increased with the advancement of age from group I to group II, but no significant differences was observed.

Cerebrum

The cerebrum was the largest part of the whole brain in both age groups of Black Bengal goats under present findings. Its shape varied from triangular to oval one and it covered completely the diencephalon and largely the midbrain. In both groups of goat, on the medial aspect the cerebral hemispheres were incompletely separated from each other by longitudinal fissure but ventrally both are connected to each other by corpus callosum which was made up of commissural fibers. Posteriorly both the cerebral hemispheres were separated from cerebellum by a transverse fissure (Fig.4). Well defined all three surfaces of cerebral hemisphere were identified in both age groups of Black Bengal goat. It was observed as dorsolateral, medial and ventral surfaces. These findings are in accordance with the observation of Suman and Pandya (2018) in brain of Surti buffalo. Under present observation, the dorsolateral surface of each cerebral hemisphere was convex and showed well demarcated sulci and gyri. In both age groups of goats, transverse fissure and longitudinal fissure was located dorsally, callosal fissure and calloso-marginal fissure was medially, and the rhinal fissure was visible on ventral surface. Each cerebral hemisphere was made up of outer grey matter and inner white matter. The outer grey matter placed externally as cerebral cortex and inner white matter as cerebral medulla which was placed inside the cortex. Present findings are in accordance with the observations of Lucy (2018) in goat foetuses, Suman and Pandya (2018) in Surti buffalo, Beulah (2021) in adult sheep. Sal-adin, (2001) in human beings, Trotter and Lumb, (1962) in bovine, Rajhavan (1964) in ox, Frandson and Whitten (1974) in farm animals, Harper and Maser (1975) in American plain buffalo, Zhaohui, *et al.* (2011) in camel, Srinivasan (2012) in ox and Getty

(2012) in bovine and equine. The fissures found in the present study were also reported by Getty, Harper and Maser and Srinivasan. In present observation, the cerebrum was divided into four different type of lobe i.e. frontal lobe, temporal lobe, parietal lobe and occipital lobe as earlier reported by Wilike (1938).

In present findings, it was noted that the length of the cerebrum in Group I varying from 3.74cm to 8.09 cm with mean value of 6.10 ± 0.39 cm. In Group II it was 6.36 ± 0.51 cm ranging from 4.04 cm to 8.95cm. In group I the mean width of each cerebral hemisphere was 3.12 ± 0.32 cm varying from 1.86 cm to 4.58cm and 2.11cm to 5.09 cm with mean of 3.38 ± 0.31 cm in group II (**Table.1 and Fig.8**). Kigir *et al.* (2010) reported that the length and depth of cerebrum was 7.18 cm and 3.81 cm respectively in Sahel goats which was slightly higher than the Black Bengal goat. Olopade *et al.* (2005) documented that the mean length of the cerebrum was 5.08 cm in West African Dwarf (WAD) sheep, however it was 5.78 cm in Sahel goats as recorded by Olopade *et al.* (2005). These differences may be due to breed variation.

In the present study the length as well as width of cerebrum was found to be increased with the advancement of age from group I to group II, but no significant differences were observed in length and width of cerebrum of goat from group I to II as earlier reported by Salankar, (2017). In contrast with the observations of the present study, Olopade *et al.* (2007) and Kigir *et al.* (2010) in goat reported decrease in length and width of the cerebrum with the advancement of age.

Cerebellum

The cerebellum was the largest part of the rhombencephalon situated behind the cerebrum and dorsal to the pons and medulla oblongata. Its rostral end was comparatively rounded and wider than the caudal end. The rostral part of cerebellum was closely associated with caudal face of cerebrum. It was separated from cerebrum by a transverse groove (fissure). The cerebellum was connected with the midbrain rostrally and the medulla oblongata caudally by the three distinct cerebellar peduncles in both age groups of goats. The cerebellum was composed of three lobes which were a centrally placed vermis and two lateral lobes. In present study the dorsal surface of cerebellum showed transverse sulci that subdivided the cerebellum into folia (**Fig.5**) as earlier reported by Byanet and Mkaanem (2017).

In mid- sagittal section of cerebellum, ten distinct lobules were observed in both age group of goats. (**Fig.6**). Number of sub-lobules were highest in the middle lobe followed by the posterior lobe while the lowest one was observed in the anterior lobe. In both groups of goats, I lobule was short and small in cranio-ventral direction, lobule II was slightly larger than the lobule I and placed cranial to the I. Lobule III was the wider than the previous and placed cranially. Lobule IV was slightly viewed dorsally, lobule V and VI were longest and widest and placed dorsally. Lobules VII, VIII and IX were caudally directed, however X was ventro-caudally placed (**Fig.6**). These findings are in accordance with observation of Byanet and Mkaanem (2017) in Red Sokoto goat. The superficial layer of the cerebellum was the gray matter and it covered the interior white matter.

In present findings, it was noted that the length of the cerebellum in Group I varying from 1.59 cm to 4.52 cm with mean value of 3.15 ± 0.29 cm. In Group II it was 3.17 ± 0.30 cm ranging from 2.01 cm to 5.04cm. In group I the mean width of cerebellum was 3.65 ± 0.44 cm varying from 1.95 cm to 6.48 cm and 2.54cm to 6.21 cm with mean of 4.14 ± 0.43 cm in group II (**Fig.7 and Table. 1**). These values indicated that there was slight increase in length and width of cerebellum with the advancement of age. This might be attributed to the progressive growth of brain tissues. Present findings agreed with the report of Salankar (2017) in goat. Byanet and Mkaanem (2017) reported that the length and width of cerebellum was 4.9 cm and 4.4 cm respectively in red Sokoto goat, which were slightly more than the present observation in Black Bengal goat. Olopade *et al.* (2005) recorded the length of cerebellum was 2.27cm in West African dwarf sheep. However, in Sahel goat the length and width of cerebellum was 2.79 cm and 2.43 cm respectively as recorded by Olopade *et al.* (2007). They stated that this occurrence of increase in length and depth of the cerebellum with the advancement of age may translate to early independence and cognitive function for young goats. There was no significant difference between the length and width of cerebellum with advancement of age as earlier reported by Salankar (2017) in goat.

ACKNOWLEDGMENT

The author is highly thankful to the Bihar Animal Sciences University, Patna for providing all

Table 1: Biometrical Observation of Brain in Black Bengal Goat of Group I And Group II.

Observation	Group I			Group II			P-value
	Sample Mean	SD	SE	Sample Mean	SD	SE	
Length of brain (cm)	7.82	1.27	.40	8.26	.98	.31	.399
Width of brain(cm)	5.27	1.30	.41	5.98	1.14	.36	.215
Length of cerebrum(cm)	6.10	1.23	.39	6.36	1.62	.51	.695
Width of cerebrum(cm)	3.12	1.01	.32	3.38	.99	.31	.570
Length of cerebellum(cm)	3.15	.94	.29	3.17	.95	.30	.967
Width of Cerebellum(cm)	3.65	1.39	.44	4.14	1.36	.43	.441

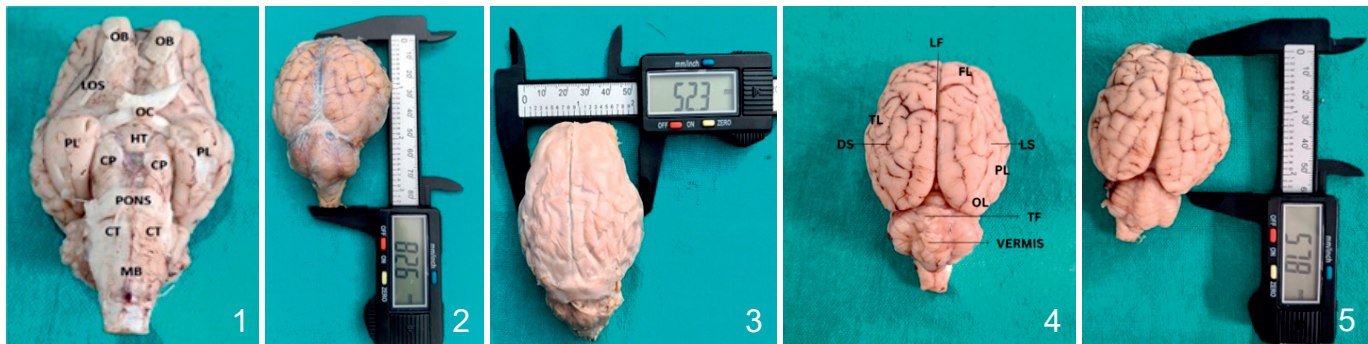


Fig. 1: Gross photograph of ventral view of brain group II goat showing olfactory lobe (OB), optic chiasma (OC), piriform lobe (PL), cerebral peduncle (CP), pons and medulla oblongata (MB); **Fig. 2:** Gross photograph showing the length of whole brain of Group I goat; **Fig. 3:** Gross photograph showing the width of whole brain of Group II goat; **Fig. 4:** Gross photograph showing cerebrum hemisphere viz. longitudinal fissure (LF) transverse fissure (TF), frontal lobe (FL), temporal lobe (TL), parietal lobe (PL) and occipital lobe (OL), dorsal surface (DS) and Lateral surface (LS) of whole brain; **Fig. 5:** Gross photograph showing length of cerebrum of Group II;

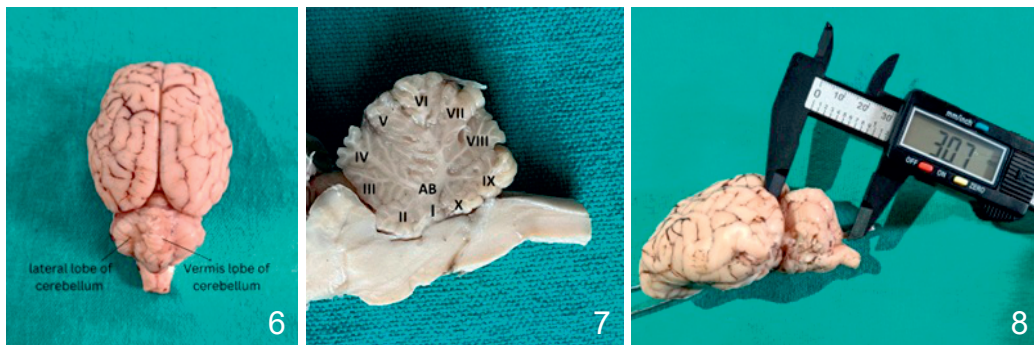


Fig. 6: Gross photograph of whole brain showing the lobes of cerebellum; **Fig. 7:** Photograph mid-sagittal section of cerebellum showing the ten distinct lobule and arbor vitae (AB); **Fig. 8:** Gross photograph showing the length of the cerebellum in Group II goat.

necessary facilities to carried out the research work.

REFERENCES

- Beulah J.V. 2021. Gross Anatomical Study of a Sheep Brain. *International Journal of Science and Research* 10 : 402-406.
- Byanet O. and Mkaanem J.D. 2017.Cerebellar cortex morphology of the Red Sokoto goat: Foliation pattern. *International Journal of Brain and cognitive sciences* 6 : 58-64.
- Fitzgerald, M. J. T., and Crossman, A. R. 2007. *Neuroanatomy: An Illustrated Colour Text*. Elsevier.
- Frandsen R. D. and Whitten E. H. 1974. *Anatomy and Physiology of Farm Animals*. 3rd Edn. pp. 324-328. Lea &Febiger, Philadelphia.
- Getty. R. 2012. *Sisson and Grossman's: The Anatomy of the Domestic Animal*. 5th Edn., pp. 1211 W.D. Saunders Company, Philadelphia
- Harper J. W. and Maser J. D. 1975. A macroscopic study of the brain of Bison bisonbison, the American plains buffalo. *Anatomy Record* 184 :187-202.
- Kavoi B. M. and Jameela H. 2011. Comparative morphometry of the olfactory bulb, tract and stria in the human, dog and goat.

- International Journal of Morphology* 29 :939-946.
- Kigir E. S., Kwari H. D. and ThilzaI. B. 2010. Some aspects of neurometrics in sahel goats in Maiduguri, Nigeria. *Academia Arena* 2 : 44-47.
- Kumar, S., Singh, Y., Kumar, P., and Singh, B. 2012. Developmental aspects of brain growth in ruminants. *Journal of Veterinary Anatomy* 23 : 12–18.
- Lucy, K. M., Harshan, K. R., Chungath, J. J., and Ashok, N. 2018. Morphogenesis of Cerebral Hemispheres in Goat Foetuses. *Indian Journal of Veterinary Anatomy* 29.
- Moss, M. L. 1978. *Postnatal growth and development of the mammalian brain*. In: *Developmental Neurobiology*. Academic Press.
- Olopade J. O., Onwuka S. K., Balogun B. A. and Oke B. O. 2005. Morphometric investigation of the brain of West African dwarf sheep in Nigeria. *International Journal of Morphology* 23 : 99-104.
- Olopade J.O., Kwari H.D., Shawulu J.C., Ofua M. and Onwuka S.K. 2007. Some aspects of the neurometrics of the Sahel goat in Nigeria. *European Journal of Anatomy*.11 : 101-104.
- Raghvan D. 1964. *Anatomy of Ox: with Comparative Notes on the Horse, Dog and Fowl*. Indian Council of Agricultural Research (ICAR), New Delhi
- Rao, A. K., Pathak, V., Rajput, R., Gupta, D., and Shukla, P. 2024. Morphological and Biometrical Study on the Hypophysis Cerebri of Gaddi Goat in Different Seasons. *Indian Journal of Veterinary Anatomy* 35 : 139-142.
- Rasouli B. and Gholami S. 2020. Histological aspect of Cerebrum and Cerebellum in Adult male and Female Mongoose (*Herpestes edwardsii*). *Iranian of Journal Medicine* 14 : 305-314.
- Saladin K.S. 2001. *The Central Nervous System, in Anatomy and Physiology; the Unity of form and Function*, McGraw-Hill, New York.
- Salankar A.M. 2017. Histological and histochemical studies on cerebrum, cerebellum, pons and medulla oblongata in goat. Ph.D. Thesis, *Maharashtra Animal and Fishery Sciences University*, Nagpur.
- Srinivasan, P. 2012. *Veterinary Anatomy of Ox*. pp. 9-15. Bio Green Books, New Delhi.
- Suman A. and Pandya S. 2018. Gross Anatomy of Cerebral Ventricles and Septum Pellucidum of Brain of Surti Buffalo (*Bubalus bubalis*). *The Indian Journal of Veterinary Sciences & Biotechnology* 14 : 14-17.
- Trotter D.M. and Lumb J.W. 1962. *Bovine Anatomy*. 2nd Edn., pp. 203- 220 Burgess Publishing Company.
- Wilkie J. 1938. The dissection and study of the sheep's brain. *Nature* 141: 896.
- Zhaohui X., Qiusheng S., Lei. Z. and Jianlin.W. 2011. Macroanatomy of basal nuclei in bacterian camel (*Camelus bactrianus*). *Journal of Camel Practice and Research* 18 : 141-144.