# HISTOMORPHOGENESIS OF TELENCEPHALON DURING THE FIRST MONTH OF GESTATION IN GOATS*

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## Abstract

*Prenatal development of the telencephalon in goats was studied using 52 foetuses ranging from 1.4 cm CRL (24 days of gestation) to 41.5 cm CRL (full term). By 24 days of age, the neural tube was completely fused and the telencephalon started to develop. Width of telencephalon was more than its height. Dorsal wall was thinner than the ventral wall and the lateral walls were the thickest. The lumen was not differentiated into the lateral ventricles. By 27 days of age (1.6 cm CRL), the lateral ventricles appeared and communicated with the third ventricle through the paired interventricular foramina of Monro. All the telencephalic parameters showed a significant positive correlation with the parameters of the other brain vesicles. Olfactory pits started to develop on either side of the telencephalon by 24 days of age. Histologically, the wall of the telencephalon by 24 days showed an inner ependymal, middle mantle and outer marginal layers bounded by the inner and outer limiting membranes. Inner ependymal layer was the thickest of all, composed of proliferating neuroepithelial cells. These cells differentiated into neuroblasts and spongioblasts that occupied the middle mantle layer. The outer non-cellular marginal layer was the thinnest, composed of growing processes of the neuroblasts.*

**Key words:** *Early histomorphogenesis, telencephalon, goat*

Neurulation in vertebrates involves thickening of the dorsal ectoderm into a neural plate, elevation of margins of the neural plate as neural folds on either side of a neural groove and fusion of the neural folds to form a neural tube. Gross anatomical and histological studies on the brain have been made in different domestic animals (Bell and Lawn, 1956; De Lahunta, 1983; Dyce *et al.*,1996; Dellmann and Eurell, 1998; Ghosh, 2002). However, early embryological changes have not been documented in ruminants. A comprehension of the cellular mechanisms is of significant importance in understanding the neural tube defects. Hence, this study was undertaken to trace the morphogenesis and histogenesis of telencephalon during the initial stages of prenatal life.

## Materials and Methods

Prenatal development of the brain was studied using 52 goat foetuses ranging from 24 days of gestation (1.4 cm crown rump length - CRL) to full term (41.5 cm CRL). Based on the age, foetuses were divided into five subgroups representing the five months of gestation. After recording the body parameters, embryos of the first month of gestation were fixed in toto in 10 per cent neutral buffered formalin, processed conventionally and serial sections of 5µm thickness were taken to trace the developmental pattern of the neural tube. The sections were stained using haematoxylin and eosin (H&E), Van Gieson's method for

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collagen, Holzer's method for glial fibres, Sevier-Munger silver impregnation method for neural tissues, aldehyde-thionine-PAS method for central nervous system, phosphotungstic acid haematoxylin (PTAH) method for central nervous system tissue, Holme's silver nitrate luxol fast blue method for axis cylinder and myelin sheath, periodic acid Schiff's reaction for carbohydrates and Best's carmine method for glycogen (Luna, 1968). To study the changes in the thickness of various layers of neural tube, the width of its entire wall and the component layers were measured using an ocular micrometer. The data were analysed statistically (Snedecor and Cochran, 1985) to find out the relationship if any, between different parameters.

## Results and Discussion

The dilated cephalic end of the neural tube is the primordium of brain. In goat embryos of 24 days of age with 1.4 cm CRL, the neural tube was completely fused and the brain vesicles started to develop. Five expansions were evident at the cranial end of the neural tube, the rostral-most being the telencephalon. The single lumen was yet to develop into the two lateral ventricles (Fig.1). Patten (1948) and Huettner (1967) reported that the brain vesicles started to differentiate in the pig embryos of 7.0mm CRL and were well established between 9.0mm and 12.0mm stage. In human embryos of about 3.0mm CRL (early fourth week), the forebrain was subdivided into its components (Arey, 1957; Truex and Carpenter, 1969 ; Sadler, 2004).

## Morphogenesis

Micrometrical parameters of the telencephalon during the first month of gestation are given in Table 1. Width of the telencephalon was more than its height. Dorsal wall was thinner than the ventral wall (Fig. 1). Lateral walls were the thickest. A similar observation was made by Shrivastava *et al.* (1987) in goats. In 24 days old embryos, the cavities within the two telencephalic vesicles were broadly continuous with the primary lumen of the neural tube. By 27 days (1.6 cm CRL), the lateral ventricles communicated with the third ventricle through the paired interventricular foramina of Monro (Fig. 2). Keith (1947) reported that in human embryos the expansion of the cerebral vesicles commenced by the end of sixth week. Lateral ventricles were long and narrow (Fig. 3). A large cavernous sinus was located near the ventral wall of telencephalon. According to Arey (1957), the telencephalon of vertebrates originated from the alar plates. Basal and floor plates were lacking, and the roof plate gave rise to the choroid plexus.

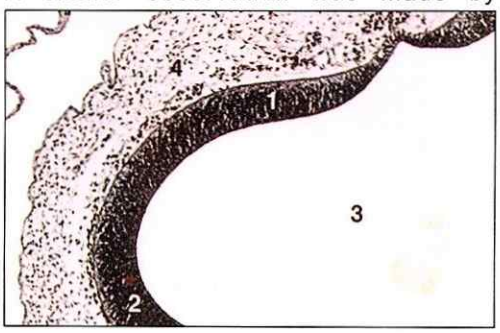



**Fig. 1.** C.S of the telencephalon (24 days of gestation). H&E. x 100.
1. Dorsal wall 2. Ventral wall 3. Lumen
4. Body wall

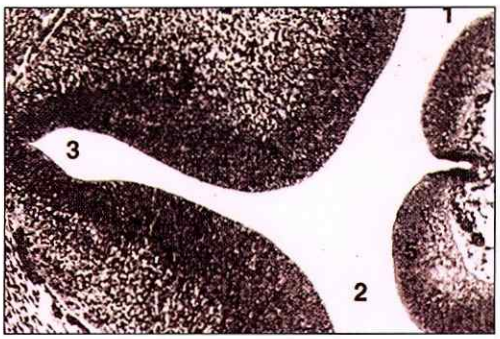



**Fig. 2.** C.S of the neural tube wall at the junction between telencephalon and diencephalon (27 days). H&E. x 100.
1. Lateral ventricle 2. Foramen of Monro
3. Third ventricle 4. Diencephalon
5. Telencephalon

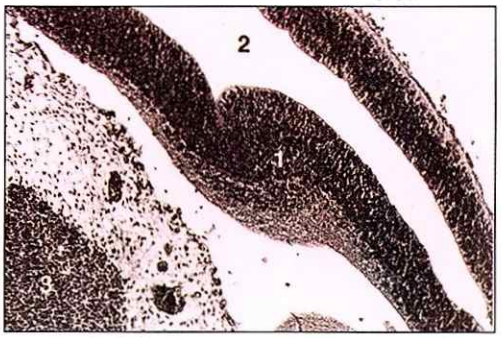



**Fig. 3** C.S of the telencephalon (27 days). H&E. x 100.
1. Wall of telencephalon 2. Lateral ventricle
3. Cavernous sinus

Near the telencephalon, olfactory pits were seen on either side (Fig. 4). Measurements of the olfactory pits are given in Table 1. The wall was lined by multilayered ectodermal epithelium consisting of columnar cells with basally located elongated nuclei. Medial wall

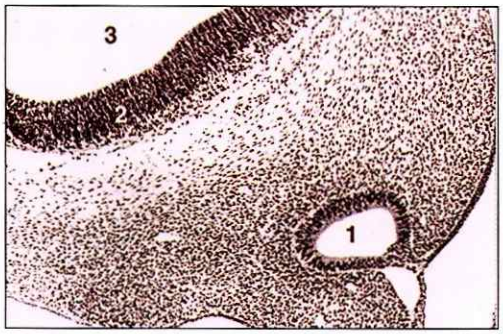



**Fig. 4.** C.S of the cephalic end of goat embryo at the cephalic end of telencephalon (24 days). H&E. x 100.
1. Olfactory pit 2. Lateral wall of telencephalon 3. Lumen of neural tube

was thicker than the lateral wall. Each olfactory pit was bordered by lateral and medial nasal processes. By 26 days of gestation, the olfactory pits were more enlarged. Similar observations were made by Arey (1957) in pig embryos. Correlation and regression coefficients of brain vesicle parameters in the first month of gestation are given in Table 2. All the telencephalic parameters showed a significant positive correlation with the parameters of the other brain vesicles.

## Histogenesis

By 24 days, external and internal limiting membranes with 4.0mm thickness bounded the wall of the telencephalon. Neuroepithelial cells were arranged radially in a pseudo-stratified manner. At this stage, wall of the telencephalon was organized into three concentric zones. Inner ependymal layer was the thickest zone and composed of elongated cells that were radially arranged about the lumen of the neural tube (Fig. 5). This

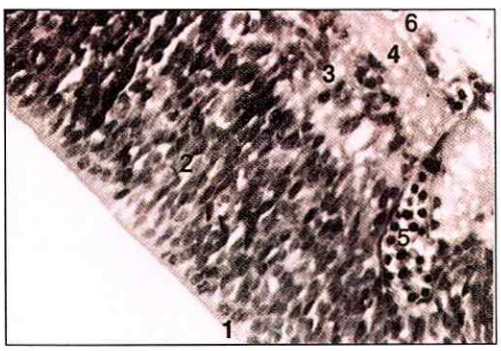



**Fig. 5.** C.S of the telencephalic wall showing a blood channel (24 days). H&E. x 400.
1.Germinal cells 2. Ependymal layer 3. Mantle layer 4. Marginal layer 5. Blood channels 6. Primitive pia mater

represented the germinal layer of proliferating neuroepithelial cells. The nucleus was elongated or oval and the cell boundaries were indistinct. Mitotic figures or germinal cells with large spherical nuclei could be seen towards the luminal surface. Similar observations were made in vertebrates by De Lahunta (1983).

Mantle layer formed one-fourth of the total width of the wall. This layer was distinguishable only in the ventral wall of developing telencephalon in 24 days-old embryos. The present results confirmed the earlier observations of Harrison (1978) in vertebrates who stated that the region of the formation of neuroblasts was mainly the basal plate. From 26 days onwards, the entire telencephalic wall showed all the three layers. The nuclei were spherical and the neuroblasts and spongioblasts were loosely arranged in the mantle layer than in the inner layer. Neuroblasts possessed larger pale staining vesicular nuclei with small dark nucleoli. By 27 days of age, the neuroblasts started developing small processes to become primitive neurons or multipolar neuroblasts. The spongioblasts were more in number and possessed smaller and darker nuclei. In vertebrates, Gilbert (1997) reported that the mantle layer became progressively thicker as more cells were added to it from the germinal neuroepithelium.

By 24 days of gestation, scattered nucleated erythrocytes were noticed in both ependymal and mantle layers. Blood channels lined by endothelial cells started penetrating into the neural tube wall from the pia mater by this stage (Fig. 5). As the development proceeded, the vascularity also increased. The outer non-cellular marginal layer was the thinnest among the three layers and was composed of the growing processes of neuroblasts in the mantle layer. This layer was limited by the external limiting membrane. By 26 days, width of the marginal layer increased and showed some spongioblasts.

In the area surrounding the external limiting membrane of the neural tube, mesenchymal cells started to condense by 24 days of age (Fig.5). Many nucleated red blood cells were also present in this region. This represented the future pia mater. Condensation of mesenchymal cells was more distinct towards the ventral wall. Peripherally, this area was surrounded by the

**Table 1.** Micrometrical parameters of telencephalon in the first month of gestation in goat foetuses, µm

| Parameters | Range (n = 6) | Mean ± S.E. |
|---|---|---|
| TELENCEPHALON | | |
| a. Total length | 3000 - 5000 | 4000.000 ± 356.148 |
| b. Total width | 1280 - 2032 | 1621.333 ± 133.461 |
| c. Total height | 816 - 1696 | 1245.333 ± 156.681 |
| d. Width of lumen | 1088 - 1536 | 1304.000 ± 77.700 |
| e. Height of lumen | 608 - 1360 | 965.333 ± 132.176 |
| LATERAL WALL | | |
| f. Total width | 96 - 120 | 130.667 ± 10.667 |
| g. Width of ependymal layer | 56 - 96 | 78.000 ± 6.673 |
| h. Width of mantle layer | 24 - 40 | 34.000 ± 2.875 |
| i. Width of marginal layer | 16 - 24 | 18.667 ± 1.687 |
| DORSAL WALL | | |
| j. Total width | 72 - 96 | 83.333 ± 4.185 |
| k. Width of ependymal layer | 40 - 48 | 46.000 ± 1.366 |
| l. Width of mantle layer | 16 - 28 | 20.000 ± 2.530 |
| m. Width of marginal layer | 16 - 20 | 17.333 ± 0.843 |
| VENTRAL WALL | | |
| n. Total width | 76 - 96 | 85.333 ± 3.676 |
| o. Width of ependymal layer | 44 - 48 | 46.667 ± 0.843 |
| p. Width of mantle layer | 16 - 28 | 21.333 ± 2.231 |
| q. Width of marginal layer | 16 - 20 | 17.333 ± 0.843 |
| OLFACTORY PIT | | |
| r. Total width | 128 - 448 | 261.333 ± 60.809 |
| s. Total height | 224 - 688 | 453.333 ± 84.731 |
| t. Width of wall | 32 - 48 | 40.000 ± 2.921 |
| u. Width of lumen | 64 - 352 | 181.333 ± 55.220 |
| v. Height of lumen | 160 - 592 | 373.333 ± 78.890 |
| ROOF PLATE | | |
| w. Thickness | 24 - 64 | 40.667 ± 6.566 |

**Table 2.** Correlation and regression coefficients of brain vesicle parameters in the first month of gestation

| Parameters | | Correlation coefficient | Regression of y on x (b±S.E.) |
|---|---|---|---|
| Independent variable (x) | Dependent variable (y) | | |
| Length of telencephalon | Length of metencephalon | 0.895** | 0.040 ± 0.010** |
| Length of telencephalon | Length of myelencephalon | 0.849** | 0.015 ± 0.005** |
| Width of telencephalon | Width of diencephalon | 0.983** | 1.627 ± 0.154** |
| Height of telencephalon | Height of diencephalon | 0.986** | 0.160 ± 0.014** |
| Height of telencephalon | Height of mesencephalon | 0.973** | 0.093 ± 0.011** |
| Height of telencephalon | Height of metencephalon | 0.822** | 0.380 ± 0.131** |
| Height of lumen of telencephalon | Height of lumen of diencephalon | 0.999** | 0.061 ± 0.004** |
| Height of lumen of telencephalon | Height of lumen of mesencephalon | 0.972** | 0.046 ± 0.006** |

** P<0.01 (significant at 1% level)

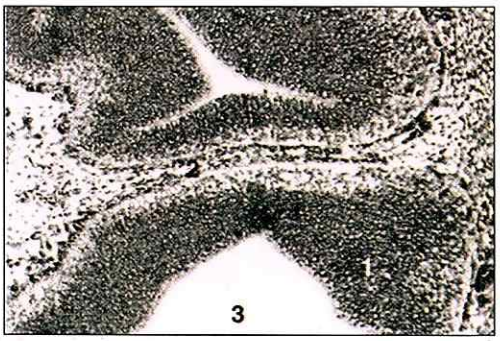



**Fig. 6.** C.S of the telencephalon showing pia mater (27 days). H&E. x 100.
1. Telencephalic wall 2. Primitive pia mater
3. Lateral ventricle

membranous cranial capsule. By 27 days, the primitive pia mater fully encircled the telencephalon (Fig.6). Similar observations were made in human embryos by Keith (1947).

## References


Arey, L.B.1957. *Developmental Anatomy*. 6th ed., W.B.Saunders Company, Philadelphia, 676 p.

Bell, F.R. and Lawn, A.M.1956. Delineation of motor areas in the cerebral cortex of the goat. *J. Physiol.*, **133**: 159-166

De Lahunta, A. 1983. *Veterinary Neuroanatomy and Clinical Neurology*. 2nd ed., W.B. Saunders Company, Philadelphia, 471p.

Dellmann, H.D. and Eurell, J.A. 1998. *Textbook of Veterinary Histology*. 5th ed., Lippincott Williams and Wilkins, Philadelphia, 380 p.

Dyce, K.M., Sack, W.O. and Wensing, C.J.G. 1996. *Textbook of Veterinary Anatomy*. 2nd ed., W.B. Saunders Company, Philadelphia, 856 p.

Ghosh, R. K. 2002. *Essentials of Veterinary Embryology*. Medical Book Company, Kolkatta, 127 p.

Gilbert, S.F.1997. *Developmental Biology*. 5th ed., Sinauer Associates, Sunderland, 473 p.

Harrison, R. G. 1978. *Clinical Embryology*. Academic Press, London, 250 p.

Huettner, A.F. 1967. *Fundamentals of Comparative Embryology of the Vertebrates*. 2nd ed., The Mac Millan Company, New York, 309 p

Keith, A. 1947. *Human Embryology and Morphology*. 6th ed., Williams and Wilkins, Baltimore, 690 p.

Luna, L.G.1968. *Manual of Histological Staining Methods of the Armed Forces Institute of Pathology*. 3rd ed., Mc Graw-Hill Book Company, New York, 258 p.

Patten, B.D. 1948. *Embryology of the Pig*. 3rd ed., The Blakiston Company, Philadelphia, p.352

Sadler, T.W. 2004. *Langman's Medical Embryology*. 9th ed., Lippincott Williams and Wilkins, Philadelphia, p.534

Shrivastava, A.M., Mehrotra, T.N. and Malik, M.R.1987. Morphogenesis of cerebrum in goat. *Indian J. Anim. Sci.* , **57**: 666-670

Snedecor, G.W. and Cochran, W.G. 1985. *Statistical Methods*. 7th ed., The Iowa State University Press, USA, 313 p.

Truex, R.C. and Carpenter, M.B.1969. *Human Neuroanatomy*. 6th ed., The Williams and Wilkins, Baltimore, 673 p.


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