PRENATAL DEVELOPMENT OF THE VENTRICULAR SYSTEM OF BRAIN IN GOATS*

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ABSTRACT

Prenatal development of the ventricular system of brain in goats was studied using 52 foetuses ranging from 1.4cm CRL (24 days of gestation) to 41.5cm CRL (full term). The dilated cavities of the brain vesicles were the forerunners of the ventricular system. Lateral ventricles appeared as a distinct entity by 26 days of gestation. Length and width of lateral ventricles increased progressively but the mean height first increased and from the fourth month onwards it gradually decreased due to the thickening of cerebral walls. Towards the end of second month, the triangular wide portion at the roof of the third ventricle was almost completely filled with choroid plexus. Third ventricle showed the infundibular, optic and pineal recesses from the second month onwards. Mesocoele was relatively broad during initial stages and the aqueduct became narrow in 76 day-old subjects. Cavity of rhombencephalon expanded to the sides by stretching of the roof plate to form the fourth ventricle at 40 days of gestation. During fifth month, the fourth ventricle was adult-like and communicated with the subarachnoid space by the foramina of Luschka. The median foramen of Magendie could not be located.

Key words: Brain ventricles, Development, Foetal goat

The dilated cavities of the brain vesicles are the forerunners of the ventricular system and these are continuous with the central canal of spinal cord. Casts of the ventricular system have been studied in different domestic animals (Stromston, 1947; Malik *et al.*, 1978; Lignereux *et al.*,1991 and Malik *et al.*, 2000). However, the developmental studies on the ventricular system of brain in ruminants are scanty. The present study deals with the prenatal development of the brain ventricles in goats which may be useful in studying the developmental anomalies associated with it.

MATERIALS AND METHODS

Prenatal development of the ventricular system of brain was studied in foetal goats of different age groups. Body weight, body parameters and skull parameters of the subjects were recorded. Age of the foetuses was calculated from the formula $W^{S!}$ = 0.096 (t-30) derived by Singh *et al.* (1979) for goat foetuses, where 'W' is the body weight of the foetus in g and 't' is the age in days. Based on age, foetuses were divided into five groups, representing the five months of gestation. Embryos of the Group 1 were fixed in toto for histological and histochemical studies. From Group 2 onwards, the head was

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separated at occipito-atlantal junction and the brain was then carefully dissected out and fixed in 10 percent neutral buffered formalin. Standard procedures were adopted for histological and histochemical studies. The sections were stained using Haematoxylin and Eosin (H&E), Van Gieson's method for 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 CNS tissue, Periodic acid Schiff's reaction for carbohydrates and Best's carmine method for glycogen (Luna, 1968). Measurements of the ventricles were taken using an ocular micrometer. The data on the physical parameters were analysed statistically (Snedocor and Cochran, 1985).

RESULTS AND DISCUSSION

By 24 days of gestation (1.4cm CRL), the embryonic lumen of the neural tube at the rostral end was divided into five regions, viz., telocoele, diacoele, mesocoele, metacoele and myelocoele. As the cerebral hemispheres developed, the cavity (telocoele) also extended into them. The dilated cavities of the brain vesicles underwent extensive alterations as a result of cellular proliferation, growth and brain flexures.

1. Lateral Ventricles

Lateral ventricles appeared as a distinct entity by 27 days of gestation (1.6cm CRL). They communicated with each other and with the third ventricle through the interventricular foramina or Foramina of Monro (Fig. 1) as observed in human embryos by Sadler (2004). Measurements of lateral ventricles at different stages of pregnancy are given in table 1. Percentage increase in length and width were 562.40 and 752.51 percent, respectively from the first month of pregnancy to the fifth month. Malik *et al.* (1978) reported that the average greatest length and width of lateral ventricles were 5.460±0.580cm and 1.250±0.080cm, respectively in the adult goat. From the present study it was concluded that the lateral ventricles attained almost half of its length and width towards term. According to Malik *et al.* (2000), the plan of ventricular system was similar in elephants, horses, goats, pigs and buffaloes. But the height of lateral ventricles was more than its width.

The lateral ventricles followed the development of cerebral hemispheres and extended into their four pairs of lobes by 48 days of gestation (4.0cm CRL). The rostral horn extended forward and downward into the frontal lobe of cerebral hemisphere and also into the olfactory bulb. The posterior horn extended into the central white matter of the occipital lobe. The choroid plexus did not extend into these horns. Inferior horn began at the junction of the body and posterior horn and curved ventrally and rostrally into the temporal lobe. The interventricular foramen was located between the column of fornix and the anterior limit of the thalamus. The roof of the ventricle was formed by the corpus callosum and the medial wall by the septum pellucidum. Septum pellucidum appeared as a well-developed partition between the two lateral ventricles by 58 days of age (7.6cm CRL). The floor was formed by the caudate nucleus in front and hippocampus caudally separated by the choroid fissure (Fig. 2) as observed by Dellmann and Mc Clure (1975) in domestic animals. Kii *et al.* (1997) observed that sex and body weight had no correlation with lateral ventricle symmetry in dogs.

2. Third Ventricle

Third ventricle or the cavity of diencephalon was an unpaired, cleft-like space lying between the two thalami and extending downward into the hypothalamus. Measurements of third ventricle at different stages of pregnancy are given in table 1. Percentage increase in length, width and height were 935.08, 280.44 and 1289.61, respectively from first month of gestation to the fifth month.

During the initial stages of pregnancy, the third ventricle was relatively broad. By 26 days of gestation (1.5cm CRL), lateral walls of the diencephalon started thickening, which compressed the lumen. By 27 days, the floor of the third ventricle appeared trough-like (Fig. 1). By 48 days of age, the two thalami grew into approximation so that the third ventricle became a slit-like cavity. It was wider in the region of the hypothalamic sulcus. At the roof portion, the third ventricle widened to form a triangular space (Fig. 3). This was almost completely filled with choroid plexus. There was only roof plate along the median plane over the small dorsal portion of the third ventricle. This was covered by a layer of pia mater, the tela choroidia, which was continuous with the pia mater lining the cerebral fissure (Fig. 3). Similar findings were made in human foetuses by Truex and Carpenter (1969).

The third ventricle showed three recesses. The funnel-like infundibular recess extended into the infundibulum while the optic recess projected ventrally in front of the optic chiasma. Posteriorly, the pineal recess extended between the habenular and posterior commissures into the stalk of the pineal body. This supports the findings made by Lignereux *et al*. (1991) in the ewe. Cilia appeared on the surface of the ependymal cells facing the third ventricle in the middle of gestation. The ependymal lining acquired its adult characteristic during fourth month. The third ventricle appeared adult-like towards the terminal stage of pregnancy.

3. Aqueduct of Sylvius

The space enclosed by the mesencephalon, the mesocoele was relatively large during the initial stages of pregnancy. It became gradually narrow by the enlargement of the corpora quadrigemina and the basal plate as reported by Larsell (1951) in human foetuses. The aqueduct began at the caudal limit of the third ventricle and opened into the rostral end of the fourth ventricle. The aqueduct became a narrow canal in 76 days-old subjects. Transverse diameter of the aqueduct during second month (0.210±0.024cm) reduced to 0.152±0.015cm in the third month. The average width was 0.346±0.044cm during the fifth month. Mean vertical diameter increased from 0.084±0.001cm to 0.214±0.017cm from the first to the fifth month (Table. 1). As in the case of mesencephalon, the transverse diameter exceeded the vertical diameter throughout gestation. The aqueduct was narrow at its beginning portion; the diameter increased at the level of rostral colliculi and the greatest width was recorded at the level of the caudal colliculi. Similar observation was made in domestic animals by Dellmann and Mc Clure (1975). The cranial part was at a higher level than the caudal portion. Lignereux *et al.* (1991) observed that the conformation of the fourth ventricle, the bending of mesencephalic aqueduct and the inclination of the general axes of the cerebrum and mesencephalon in the ewe were similar to those of the cow.

Ciliated ependymal cells lined the wall of the aqueduct and these were multilayered up to 62 days of age. At the age of 76 days, this was pseudostratified (Fig. 4). By 81 days, a single layer of ciliated columnar cells appeared. Typical adult-like ependyma could be noticed at 144 days. These observations support the studies conducted in the foetal sheep and goats by Rajtova (1999). Ependymal cells under the caudal commissure were heavily modified to form the subcommissural organ, which appeared during the second month of gestation.

4. Fourth Ventricle

Lumen of the hindbrain (metacoele and myelocoele) was diamond-shaped in cross section by 24 days of gestation. Due to the thickening of the basal plates, the lumen became coffin-shaped at 26 days of age. By 27 days, it was slit-like except at the region of the sulcus limitans.

Stretching of the roof plate to form thin roof of the fourth ventricle commenced at 40 days of gestation (Fig. 5). This thin layer formed of ependymal cells constituted the anterior and posterior medullary vela. Cavity of the rhombencephalon expanded to the sides to form the fourth ventricle. Ventrolateral wall of this cavity was demarcated by the sulcus limitans into a ventromedial basal plate and dorsolateral alar plate. Similar observations were made in the dog foetus by Jenkins (1978). During the third month of gestation, dorsal surface of the brainstem that formed floor of the fourth ventricle was marked by a deep median sulcus that became shallower rostrally as reported by Dyce *et al*. (1996) in domestic animals.

Measurements of the fourth ventricle at different stages of gestation are given in table 1. During fifth month, the fourth ventricle was adult-like and was bounded by the rhomboid fossa ventrally, cerebellar peduncles laterally and rostral and caudal medullary vela and cerebellum dorsally. Ventricular system communicated with the subarachnoid space by the foramina of Luschka (Fig. 6). The median foramen of Magendie could not be located which is in accordance with the findings of Dellmann and Mc Clure (1975) in domestic animals, Malik *et al.* (1978) in goat and Malik *et al.* (2000) in elephant. Caudally, the fourth ventricle was continuous with the central canal of spinal cord. Area prostrema, the circumventricular organ associated with the fourth ventricle could be located at this region. Knowledge on the developmental pattern of the ventricular system and their measurements may be useful in studying the developmental anomalies associated with it.

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Table 1

Measurements of ventricles of brain of goat foetuses at different ages, cm

Parameters	1st month		2nd month		3rd month		4th month		5th month	
	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE
Lateral ventricle										
a. Length	0.285-0.481	0.383 ±0.036	0.518-0.819	0.749 ±0.049	1.244-1.674	1.434 ±0.070	2.010-2.367	2.153 ±0.054	2.316-2.743	2.537 ±0.059
b. Width	0.054-0.077	0.065 ±0.039	0.213-0.269	0.241 ±0.011	0.272-0.350	0.306 ±0.014	0.392-0.424	0.417 ±0.012	0.530-0.576	0.554 ±0.008
c. Height	0.061-0.136	0.097 ±0.013	0.235-0.458	0.345 ±0.048	0.384-0.450	0.417 ±0.012	0.280-0.293	0.288 ±0.002	0.136-0.189	0.163 ±0.009
Inter ventricular Foramen										
d. Width	0.011-0.014	0.013 ±0.001	0.045-0.050	0.047 ±0.001	0.040-0.066	0.051 ±0.004	0.029-0.034	0.032 ±0.001	0.021-0.026	0.023 ±0.009
Third ventricle										
e. Length	0.125-0.148	0.134 ±0.003	0.500-0.590	0.537 ±0.014	0.541-0.835	0.703 ±0.047	0.917-1.241	1.087 ±0.053	1.042-1.877	1.387 ±0.152
f. Width	0.029-0.064	0.046 ±0.006	0.064-0.074	0.069 ±0.002	0.076-0.093	0.089 ±0.004	0.136-0.157	0.145 ±0.003	0.171-0.178	0.175 ±0.001
g. Height	0.075-0.080	0.077 ±0.001	0.224-0.584	0.403 ±0.078	0.642-0.707	0.677 ±0.013	0.707-0.914	0.865 ±0.032	1.058-1.080	1.070 ±0.003
Aqueduct of Sylvius										
h. Length	0.154-0.158	0.156 ±0.001	0.614-0.819	0.728 ±0.032	0.807-0.981	0.888 ±0.028	0.899-0.934	0.913 ±0.005	0.907-1.300	1.146 ±0.064
i. Transverse diameter	0.064-0.101	0.085 ±0.001	0.152-0.272	0.210 ±0.024	0.125-0.202	0.152 ±0.015	0.200-0.216	0.209 ±0.021	0.336-0.365	0.346 ±0.044
j. Vertical diameter	0.082-0.086	0.084 ±0.001	0.088-0.134	0.112 ±0.008	0.093-0.184	0.130 ±0.017	0.186-0.200	0.193 ±0.021	0.208-0.219	0.214 ±0.017
Fourth ventricle										
k. Length	0.150-0.162	0.155 ±0.002	0.040-0.400	0.311 ±0.029	0.402-0.610	0.566 ±0.033	0.688-0.818	0.735 ±0.019	1.280-2.102	1.463 ±0.013
l. Width	0.064-0.090	0.080 ±0.005	0.157-0.261	0.210 ±0.021	0.328-0.560	0.434 ±0.042	0.564-0.600	0.586 ±0.005	0.602-0.802	0.702 ±0.043
m. Height	0.056-0.078	0.068 ±0.004	0.144-0.157	0.150 ±0.002	0.192-0.248	0.229 ±0.097	0.243-0.304	0.269 ±0.009	0.392-0.408	0.402 ±0.012

(Number of samples = 6)

Fig. 1

C.S. of the neural tube at the junction between telencephalon and diencephalon (27 days). H&E. x 100

1. Lateral ventricle 2. Third ventricle 3. Thalamus 4. Hypothalamus
5. Floor of third ventricle 6. Foramen of Monro

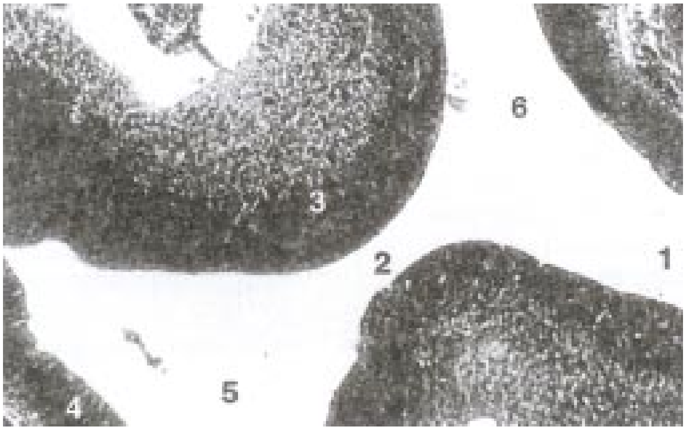

Fig. 2

C.S. of the cerebrum and diencephalon (48 days). H&E. x 100

1. Thalamus 2. Caudate nucleus 3. Choroid fissure 4. Hippocampus 5. Choroid plexus
6. Lateral ventricle 7. Velum interpositum

Fig. 3

C.S. through the dorsal portion of third ventricle showing choroid plexus (58 days). H&E. x 100

1. Pia mater 2. Venous sinus 3. Roof plate 4. Choroid plexus 5. Third ventricle

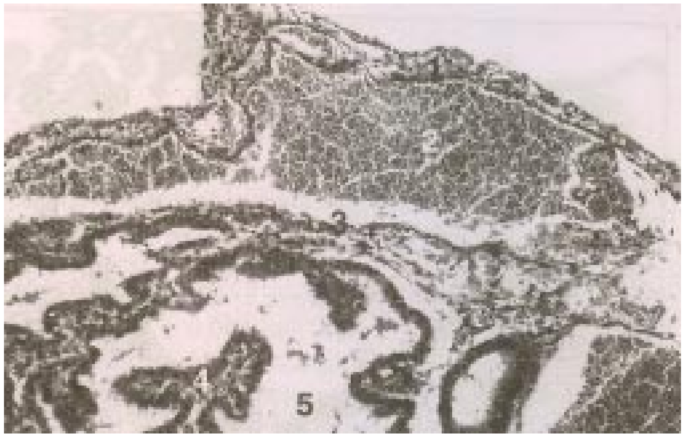

Fig. 4

C.S. of the aqueduct showing pseudostratified ciliated ependymal cells (76 days). H&E. x 400

1. Ependymal cells with cilia 2. Aqueduct of Sylvius

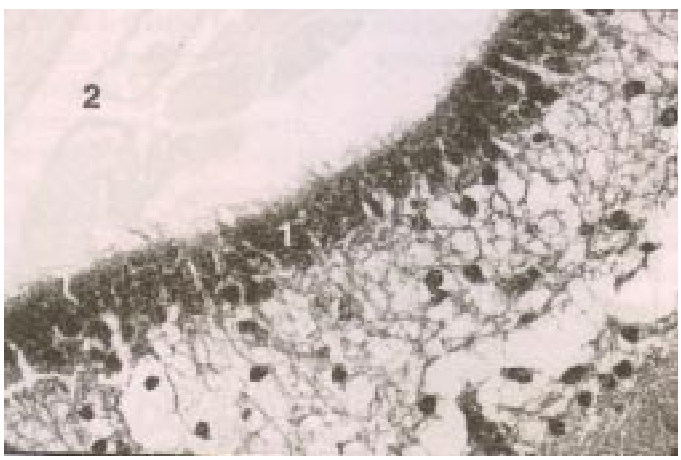

Fig. 5

C.S. of the medulla oblongata showing caudal medullary velum and the choroid plexus of the fourth ventricle (48 days). H&E. x 100

1. Caudal medullary velum 2. Choroid plexus 3. Fourth ventricle 4. Medulla oblongata 5. Nuclear aggregation 6. Median sulcus 7. Sulcus limitans

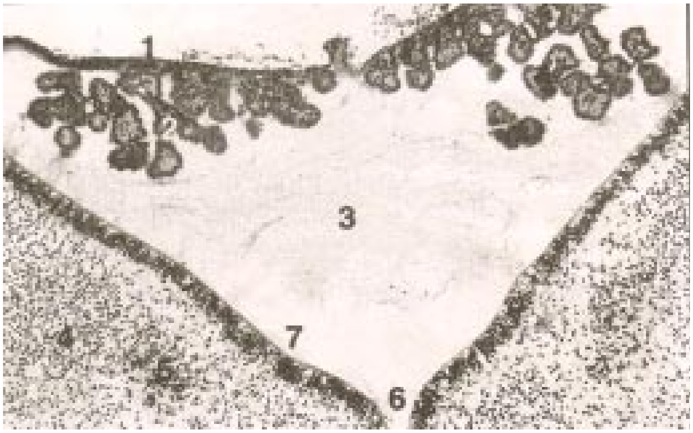

Fig.6

C.S.of the medulla oblongata showing foramen of Luschka and caudal medullary velum (76 days). H&E. x 100

1. Caudal medullary velum 2. Medulla Oblongata 3. Choroid plexus 4. Sulcus limitans 5. Foramen of Luschka