MORPHOGENESIS OF MEDULLA OBLONGATA IN GOAT FOETUSES*

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ABSTRACT

Prenatal morphogenesis of medulla oblongata (MO) was studied using 46 goat foetuses ranging from 2.5 cm CRL (40 days of gestation) to 41.5 cm CRL (full term). By 40 days of gestation, the roof plate region of the rhombencephalon expanded enormously and as a result, the entire alar and basal plates of the neural tube were displaced laterally and ventrally. Nuclei first appeared in medulla by 48 days (4.0 cm CRL) and nerve fibres crossing in different directions broke up the gray substance into a mixture of gray and white mater, the reticular formation. Trapezoid body started developing by 48 days. Medullary pyramids appeared on the ventral surface by 81 days of age (13.0 cm CRL). Percentage contribution of medulla oblongata to the total brainstem weight increased progressively during gestation (from 13.90 percent in second month to 17.57 percent in the fifth month). When compared to cerebrum and cerebellum, the MO along with the other regions of the brainstem was noted to be a slow growing region. During second month, contribution of MO to the total brain weight was 4.69 percent, which gradually reduced to 3.46 percent in the fifth month indicating rapid growth of the region in the first half of gestation followed by a gradual "cephalic shift" of function from phylogenetically older brainstem to the higher cerebral and cerebellar cortices. Towards term, this region was well developed and the relative maturity of the MO in goats at birth justifies the classification of goat as a prenatal brain developer.

Key words: Medulla oblongata, Prenatal development, Goat.

INTRODUCTION

Medulla oblongata is the caudal portion of the brain, located between the pons rostrally and spinal cord caudally, resting on the basioccipital bone. Postnatal studies on the histomorphology of the hindbrain have been made in different domestic animals (Jenkins, 1978; King, 1987; Rizzo, 2006 and Konig and Liebich, 2007). However, prenatal developmental changes have not been well documented in ruminants. Hence, this study was planned to investigate prenatal morphogenesis of medulla oblongata in goats.

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MATERIALS AND METHODS

Prenatal morphogenesis of medulla oblongata (MO) in goats was studied using 46 goat foetuses ranging from 2.5 cm CRL (40 days of gestation) to 41.5 cm CRL (full term). The material available in the Department of Anatomy and those collected from the farms and clinics were used for the study. Body weight, body parameters and skull parameters of the subjects were recorded. The age of the foetuses was calculated from the formula, $W^{0.33} = 0.096$ (t-30) derived by Singh *et.al*. (1979) for the goat foetuses, where 'W' is the body weight of the foetus in g and 't' is the age of the foetus in days. Based on the age, the foetuses were divided into four groups representing second, third, fourth and fifth months of gestation. The heads were separated at the occipito-atlantal junction and the brain was then carefully dissected out and fixed in 10 percent neutral buffered formalin. After recording the whole brain parameters, the MO was separated at the caudal border of the pons (rostral boundary) and the rostral limit of origin of first pair of cervical spinal nerves (caudal boundary). Measurements were taken and the data were analysed statistically (Snedecor and Cochran, 1985). Standard procedures were adopted for histoarchitectural studies (Luna, 1968).

RESULTS AND DISCUSSION

Development in the Second Month

Medulla oblongata, the caudal most segment of the brainstem, extended from the level of first pair of cervical spinal nerves to the caudal edge of the pons (Fig. 1). It lay on the unossified basioccipital and this cartilaginous skeleton developed in the sixth week of gestation. Measurements of medulla oblongata at different stages of gestation are given in table 1. By 40 days, the roof plate region of the embryonic rhombencephalon expanded enormously. As a result, the entire alar and basal plates of the neural tube were displaced laterally and ventrally. Arey (1957) compared this to an opened book whose hinge was the floor plate. The lumen became the fourth ventricle covered dorsally by the thin, single layer of ependyma, the roof plate. This constituted the anterior and posterior medullary vela (Figs. 2 and 3). These vela were continuous with the cerebellum cranially and the roof of the central canal of spinal cord caudally. The sulcus limitans present on the ventrolateral wall of the fourth ventricle provided the plane of division of the medulla into a ventromedial basal plate and a dorsolateral alar plate. Similar observations were made in dog foetuses by Jenkins (1978). The lumen was filled with CSF. Nuclei appeared by 48 days and nerve fibres crossing in different directions broke up the gray substance into a mixture of gray and white known as the reticular formation. The trapezoid body started developing at 48 days (4 cm CRL). The point of emergence of the facial nerve from the medulla is illustrated in figure 4. The endolymphatic duct also could be seen within the petrous temporal.

Vascular mesenchyme occupied the ependymal roof; the combined membrane, the tela choroidea, infolded as vascular tufts into the cavity of the myelencephalon constituting the choroid plexus of the fourth ventricle. This developed in the goat foetus in the sixth week of gestation. Keith (1947) reported that the choroid villi developed on the ventricular surface of the caudal medullary velum at eight weeks in the human foetus and CSF was being produced during the third month. Later during the seventh week, the ependymal roof plate became broad and thin. The cavity of the rhombencephalon thus expanded to the sides, flattened dorsoventrally and was filled with CSF. The rhombic lip, ridge where the tela joined the alar plate was made up of three to four layers of cells. Harrison (1978) reported that the cells of rhombic lip were actively mitotic and provided large number of neuroblasts, which migrated cephalad into the ventral aspect of the hindbrain where they formed the pontine nuclei and the olivary nuclear complex.

Caudally the medulla oblongata was continuous with the spinal cord. The fourth ventricle narrowed posteriorly to be continued as the central canal of spinal cord. Dorsal wall of this region showed thickened epithelium constituting the circumventricular organ. Medulla oblongata contributed 4.69 percent of the brain weight and 13.90 percent of the brainstem weight at this stage.

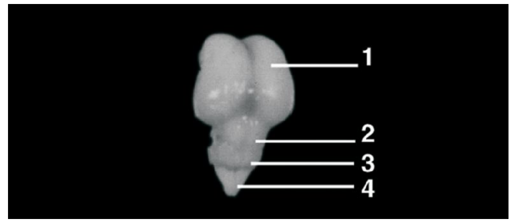

Fig. 1 Dorsal surface of brain (55 days)
1. Cerebrum; 2. Corpora quadrigemina;
3. Cerebellum; 4. Medulla oblongata

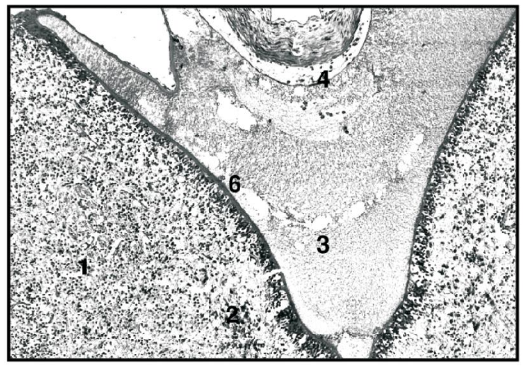

Fig. 2 C.S. of the medulla oblongata at the level of rostral medullary velum (48 days). H&E. x 100
1. Medulla oblongata; 2. Nuclear aggregation;
3. Fourth ventricle with CSF; 4. Rostral medullary velum;
5. Body wall; 6. Internal glial limiting membrane

Table 1. Measurements of medulla oblongata (MO) of goat foetuses at different ages

Parameters	2nd month (n=10)		3rd month (n=12)		4th month (n=10)		5th month (n=14)	
	Range	Mean ±S.E.	Range	Mean ±S.E	Range	Mean ±S.E	Range	Mean ±S.E
Weight of MO (g)	0.030-0.070	0.052 ±0.006	0.080-0.350	0.220 ±0.032	0.390-0.520	0.437 ±0.016	0.540-2.000	1.411 ±0.134
Length of MO (cm)	0.500-0.630	0.564 ±0.019	0.620-1.030	0.805 ±0.053	1.100-1.300	1.183 ±0.027	1.440-2.300	1.869 ±0.072
Maximum width of MO (cm)	0.440-0.510	0.475 ±0.011	0.520-0.800	0.702 ±0.030	0.810-1.000	0.855 ±0.019	1.100-1.600	1.447 ±0.038
Minimum width of MO (cm)	0.240-0.310	0.284 ±0.010	0.320-0.410	0.384 ±0.009	0.420-0.500	0.467 ±0.010	0.510-0.900	0.740 ±0.035
Thickness of MO (cm)	0.240-0.400	0.308 ±0.022	0.400-0.530	0.468 ±0.014	0.600-0.710	0.682 ±0.011	0.710-1.000	0.839 ±0.023
Length of medullary pyramids (cm)	Not fully developed		0.680-0.890	0.805 ±0.031	0.890-1.000	0.926 ±0.011	1.080-1.980	1.585 ±0.088
Width of medullary pyramids (cm)	Not fully developed		0.200-0.270	0.230 ±0.013	0.340-0.600	0.444 ±0.033	0.620-0.720	0.656 ±0.008
Craniocaudal length of trapezoid body (cm)	Not fully developed		0.100-0.150	0.117 ±0.005	0.200-0.260	0.230 ±0.007	0.270-0.320	0.298 ±0.003

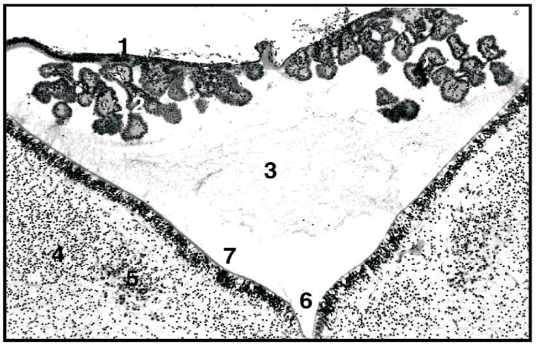

Fig. 3 C.S. of the medulla oblongata at the level of caudal medullary velum (48 days). H&E. x 100
1. Caudal medullary velum; 2. Choroid plexus; 3. Fourth ventricle with CSF; 4. Medulla oblongata; 5. Nuclear aggregation; 6. Median sulcus; 7. Sulcus limitans

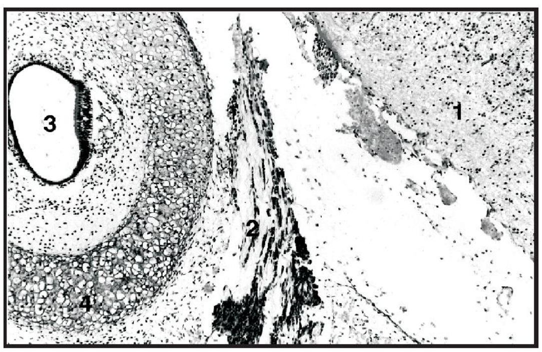

Fig. 4 C.S. of the medulla oblongata showing the facial nerve and endolymph duct (48 days). H&E.x100
1. Medulla oblongata; 2. Facial nerve; 3. Endolymph duct; 4. Petrous temporal bone

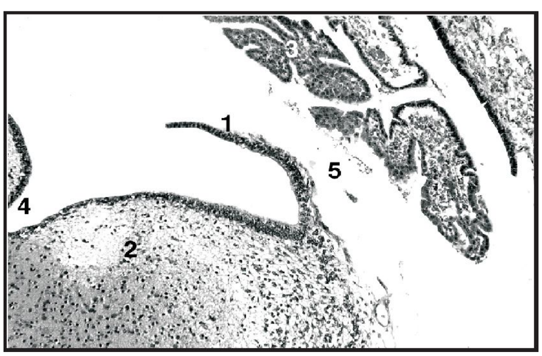

Fig. 5 C.S. of the medulla oblongata showing foramen of Lushcka and caudal medullary velum. (76 days). H&E. x 100 1. Foramen of Lushcka; 2. Caudal medullary velum; 3. Choroid plexus; 4. Sulcus limitans

Development In The Third Month

The medullary pyramids could be distinguished from 81 days (13 cm CRL) and were in the form of longitudinal ridges on either side of the ventral median fissure but they were not widely separated in the rostral portion. These agree with the findings of Dellmann and Mc Clure (1975) in small ruminants. However, in cattle the pyramids were widely separated at the point of emergence from the caudal aspect of pons.

The dorsal surface of the medulla formed the floor of fourth ventricle as noted in the second month. The caudal medullary velum projected from the dorso-medial angle of medulla oblongata. The fourth ventricle communicated with the subarachnoid space by the foramen of Lushcka (Fig. 5). Floor of the ventricle was marked by a deep median sulcus, which became shallower rostrally. On each side of the median sulcus was a continuous ridge, the medial eminence, bounded laterally by the sulcus limitans as observed by Truex and Carpenter (1969) in man and Dyce *et al.* (1996) in domestic animals. The medial eminence, or trigonum hypoglossi was formed by the nucleus of hypoglossal nerve. The lateral eminence was occupied by the caudal poles of the medial and inferior vestibular nuclei. In between the medial and lateral eminences was the intermediate eminence, the trigonum vagi.

Mean weight of medulla oblongata was 0.220 ± 0.032g during third month. Width of medulla oblongata was more than its height throughout gestation. Average length and width of medullary pyramids were 0.805 ± 0.031cm and 0.230 ± 0.013cm, respectively. The trapezoid body was clearly demarcated and the mean rostrocaudal distance was 0.117 ± 0.005cm.

Dellmann and Mc Clure (1975) reported that the trapezoid body was more clearly demarcated in small ruminants than in cattle.

Development In The Fourth Month

Medulla oblongata contributed 17.57 percent of the brainstem weight. Percentage contribution of medulla oblongata to the total brainstem weight increased progressively during gestation. During the fourth month, mean length, width and thickness of the medulla oblongata were 1.183 ± 0.027cm, 0.855 ± 0.019cm and 0.682 ± 0.011cm, respectively. Unlike in the pons region, maximum width of medulla oblongata exceeded the maximum height. Morphological features did not change much during the fourth month. Length and width of medullary pyramids increased 15.03 and 93.04 percent, respectively from third to fourth month. More increase in width corresponded to growth of cerebrum since these fibres have their origin in the cerebral cortex.

Development In The Fifth Month

Trapezoid body was clearly demarcated from the pons. Cranio-caudal length of trapezoid body was 0.298 ± 0.003cm. Mean weight of medulla oblongata increased three-fold during fifth month. Corresponding changes were also noticed in the length, height and width of medulla oblongata (Table. 1). During second month contribution of medulla oblongata to the total brain weight was 4.69 percent which gradually reduced to 3.46 percent in the fifth month indicating rapid growth of the region in the first half of gestation followed by a gradual "cephalic shift" of function from phylogenetically older brainstem to the higher cerebral and cerebellar cortices. When compared to other divisions of brain, the medulla oblongata along with other regions of brainstem was noted to be a slow growing region. Ventral median fissure was flanked by the pyramids. Mean length and width of medullary pyramids were 1.585 ± 0.088 cm and 0.656 ± 0.008 cm, respectively. Grossly, medulla oblongata was adult-like during the fifth month (Fig. 6).

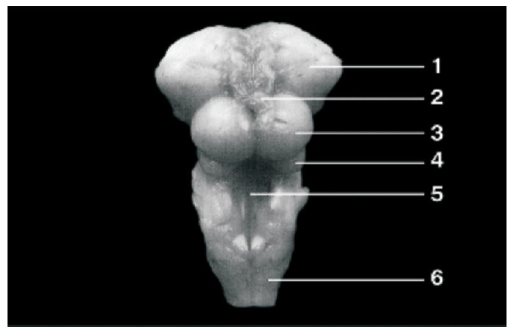

Fig. 6 Dorsal view of brainstem (124 days)
1. Thalamus; 2. Pineal gland; 3. Rostral colliculus;
4. Caudal colliculus; 5. Fourth ventricle;
6. Medulla oblongata

The medulla oblongata is a great suprasegmental conveyor and co-ordinator for pathways and nuclei involved with vital regulatory and protective processes which affect the whole body. Towards term, this region was well developed and the relative maturity of the MO in goats at birth justifies the classification of goat as a prenatal brain developer. Foetal brain is most vulnerable when it is growing rapidly and nutritional deficiencies and diseases during the growing period can cause permanent damage.

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