Histological Studies on the Development of Cerebrum in Goat Foetuses

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ABSTRACT

Histogenesis of cerebrum was studied using 52 goat foetuses ranging from 1.4cm CRL (24 days of gestation) to 41.5cm CRL (full term). Standard procedures were adopted for histoarchitectural studies. At 24 days (1.4cm CRL), wall of the developing telencephalon showed an inner ependymal, middle mantle and outer marginal layers. Towards the middle of 2nd month, neuroblasts and spongioblasts of the inner ependymal layer of the cerebral wall migrated outwards giving rise to a superficial gray cortex. By 48 days, this cortical plate showed outer molecular and inner cellular layers. By 76 days, the cortex revealed four layers, viz., outer molecular, superficial granular, intermediate granular and deep granular layers. Cortical migration came to an end by about 12 weeks and the cells were undergoing differentiation during the 4th month. During 5th month, the neocortex was divided into six layers. Cortex was thicker at the top of the gyrus and the mean thickness decreased from 4th to 5th month.

Key Words: Histogenesis, cerebrum, goat
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Though extensive research has been done on mammalian brain (Ferrer et al., 1986; Gilbert, 1997), information regarding the developmental changes has not been well documented in ruminants. Foetal central nervous system is most vulnerable when it is growing rapidly and nutritional deficiencies and diseases during the growing period can cause permanent damage. Therefore, a comprehensive study on the histogenesis of cerebrum in goats seems to be a relevant area of research.

MATERIALS AND METHODS:

Histogenesis of cerebrum was studied using 52 goat foetuses ranging from 1.4 cm CRL (24 days of gestation) to 41.5 cm CRL (full term). The material was collected from the department, farms and clinics. The age of the foetuses was calculated from the formula, \( W^{1/3} = 0.096 \times (t-30) \) derived by Singh et al. (1979) for the goat foetuses, where ‘\( W \)’ is the body weight of the foetus and ‘\( t \)’ is the age of the foetus in days. Based on age, the foetuses were divided into five groups representing five 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. Standard procedures were adopted for histoarchitectural studies. Measurements were taken using an ocular micrometer. The data were analysed statistically (Snedsocor and Cochran, 1985).

RESULTS AND DISCUSSION

Development in the First Month

At 24-days of age (1.4 cm CRL), dilated cephalic end of the neural tube showed five brain vesicles, viz., telencephalon, diencephalon, mesencephalon, metencephalon and myelencephalon. Histologically, wall of the developing telencephalon showed an inner ependymal, middle mantle and outer marginal layers bounded by the internal and external limiting membranes (Fig. 1).

Development in the Second Month

Wall of the cerebral hemisphere showed the three layers up to 40 days of gestation (2.5 cm CRL). A septum pellucidum appeared as a well-developed partition between the two lateral ventricles at 58 days (7.6 cm CRL). According to Truex and Carpenter (1969), in human beings, the septum pellucidum was made up of two thin plates of neural tissue, between which there was a space, the cavum pellucidum. Similar structures could not be identified in the present study.

Neuroblasts and spongiosblasts of the inner ependymal layer left this zone and migrated outwards through the mantle layer into the marginal layer thereby giving rise to a superficial primordial grey cortex (Fig. 2). This is in accordance with the observations made in vertebrates by Arey (1957), Kappers et al. (1967) and Harrison (1978). The position of gray and white substances of the spinal cord was largely reversed in the cerebrum and cerebellum. This is in accordance with the findings in various domestic animals by Ghosh (2002).

The middle zone formed the white medullary mass of cerebral hemispheres. In some areas wavy lines of neuroblasts could be seen (Fig. 3). According to Arey (1957), such changing relations through mass migration of neuroblasts to new locations has been named as neurobiotaxis. According to Gilbert (1997), these migrating neurons moved radially along the glial processes after their final mitosis. A single cell in the ventricular layer could produce neurons and glial cells in any of the cortical layers. But how these cells enter a particular layer is not known. Once the cells arrived their final destination, it is thought that they elaborate particular adhesion molecules that organised them together as brain nuclei.

In 48 days-old foetuses, the outer zone or cortical plate showed two distinct layers. The outer marginal layer was composed mostly of fibres and became the molecular or plexiform layer (Fig. 4). The inner cellular layer represented the future layers II to VI of the fully developed cortex. Neurons of this layer were small cells with dark compact nuclei and inconspicuous cytoplasm. Similar observations were made in goat foetuses by Shrivastava et al. (1987).

Towards the end of 2nd month, cortical migration of neuroblasts was very much pronounced. Stratification of the granular layer into various zones was not evident in this stage. Vascularity of the cerebral wall greatly increased at this stage. This is in accordance with the observations made in vertebrates by Gilbert (1997).

Development in the Third Month

During initial stages of third month (61 days of gestation), the cortical plate showed only two layers, viz., the outer molecular layer and the inner cellular layer. By the middle of third month, the inner cellular layer showed stratification. Thus at the age of 76 days (12.0 cm CRL), the cerebral cortex revealed four layers, viz., the outer molecular, superficial granular, intermediate granular and the deep granular layers (Fig. 5). According to Larsell (1951), this happened in human embryos during the fourth and fifth month of gestation. Shrivastava et al. (1987) reported that the cerebral cortex was differentiated into four layers in goat foetuses of 2.7 cm to 4.4 cm CRL.

Cerebral cortex was thicker at the top of the crown of gyrus and the thickness gradually diminished towards the floor of the sulcus. Similar observations were made in human foetus by Kappers et al. (1967). The reasons for these variations were explained to be mechanical differences in the compression or stretching of the various layers. Deeper layers were more vascular compared to the outer layers.

Development in the Fourth Month

Histological picture of the cerebral mantle was same as that observed during the third month, but the width of various layers increased (Fig. 6). Pyramidal cells of the cerebral cortex were not differentiated during the fourth month. Unlike in the third month, white matter did not reveal waves of migrating cells. Width of white matter further increased. The inner ependymal layer became extremely thin by 101 days of age with pseudostratified ciliated columnar ependymal cells. Reports on this aspect are not available for comparison.

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Development in the Fifth Month

Thickness of the cerebral cortex decreased when compared to that in the 4th month. Tej and Jain (2014) reported that blood supply to the cerebrum in goat was by means of cranial, middle and caudal cerebral arteries derived from the rete mirabilis. Larsell (1951) reported that about two-thirds of the total area of the cortex was hidden in the folds of sulci and fissures. Truex and Carpenter (1969) noticed that the cortex was always thickest over the crest of a convolution and thinnest in the depth of a sulcus.

During fifth month, the neocortex could be divided into six layers as in adults. Contrary to this, Shrivastava et al. (1987) described the cerebral cortex of foetal goat as heterogenetic type that did not reveal six distinct layers. Ferrer et al. (1986) compared the 6th layer of cerebral cortex in carnivores, Artiodactyla and primate brains and observed a basic structural uniformity in all these species.

Truex and Carpenter (1969) reported that this contained the terminal dendritic ramifications of the pyramidal and fusiform cells from the deeper layers. Similar observations have been made in goat foetuses by Shrivastava et al. (1987).

The external granular layer consisted of numerous closely packed small cells (Fig.7). External pyramidal layer was composed mainly of typical pyramidal neurons of two categories (Fig. 8). Internal pyramidal layer consisted principally of large pyramidal neurons that measured 37.50µm at 144 days with a nucleus measuring 15.00µm.

The white matter filled in the space between cortex, ventricle and basal nuclei, formed the medullary core of the various convolutions. Similar observations were made in domestic animals by King (1987).

REFERENCES


Fig. 1  C.S. of the wall of telencephalon. (24 days). H&E. x 100. 1. Internal limiting membrane 2. Ependymal layer 3. Mantle layer 4. Marginal layer 5. External limiting membrane 6. Condensation of pia mater 7. Lumen of telencephalon

Fig. 2  C.S. of the lateral cerebral wall showing migration of cells. (48 days). H&E. x 100. 1. Lateral ventricle 2. Ependymal layer 3. Mantle layer 4. White matter 5. Superficial gray cortex 6. Pia mater

Fig. 3  C.S. of the cerebral wall showing wavy lines of migrating neuroblasts. (58 days). H&E. x 100. 1. Lateral ventricle 2. Ependymal layer 3. Mantle layer 4. White matter 5. Wavy lines of migrating cells
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Table 1. Micrometrical parameters of cerebral wall of goat foetuses during second, third and fourth month of gestation, µm

<table>
<thead>
<tr>
<th>Parameters</th>
<th>2nd m.</th>
<th>3rd m.</th>
<th>4th m.</th>
<th>2nd m.</th>
<th>3rd m.</th>
<th>4th m.</th>
<th>2nd m.</th>
<th>3rd m.</th>
<th>4th m.</th>
<th>2nd m.</th>
<th>3rd m.</th>
<th>4th m.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total thickness</td>
<td>962.67±44.32</td>
<td>2082.67±321.77</td>
<td>3245.33±75.09</td>
<td>797.33±56.25</td>
<td>1442.67±228.32</td>
<td>2344.00±51.23</td>
<td>680.00±12.22</td>
<td>864.00±26.77</td>
<td>1733.33±114.76</td>
<td>1394.67±39.93</td>
<td>2376.00±288.91</td>
<td>3448.00±37.12</td>
</tr>
<tr>
<td>Thickness of cerebral mantle</td>
<td>317.33±20.41</td>
<td>669.33±80.68</td>
<td>1757.33±37.05</td>
<td>200.00±9.91</td>
<td>474.67±63.29</td>
<td>1248.00±20.24</td>
<td>184.00±3.58</td>
<td>280.00±13.55</td>
<td>578.67±50.67</td>
<td>338.67±9.62</td>
<td>674.67±76.56</td>
<td>1824.00±38.53</td>
</tr>
<tr>
<td>Width of molecular layer</td>
<td>80.00±3.58</td>
<td>82.67±9.62</td>
<td>321.33±10.21</td>
<td>56.00±2.92</td>
<td>109.33±22.78</td>
<td>224.00±4.13</td>
<td>34.67±1.69</td>
<td>52.00±4.84</td>
<td>122.67±15.27</td>
<td>73.33±3.21</td>
<td>75.33±5.51</td>
<td>341.33±5.33</td>
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<tr>
<td>Width of outer granular layer</td>
<td>36.00±3.43</td>
<td>146.67±23.88</td>
<td>401.33±8.86</td>
<td>30.67±3.21</td>
<td>57.33±6.85</td>
<td>296.00±1.69</td>
<td>34.67±2.92</td>
<td>48.00±27.28</td>
<td>89.33±15.27</td>
<td>57.33±3.21</td>
<td>134.67±20.07</td>
<td>420.00±10.07</td>
</tr>
<tr>
<td>Width of inner granular layer</td>
<td>124.00±7.08</td>
<td>256.00±24.44</td>
<td>560.00±9.24</td>
<td>61.33±4.53</td>
<td>197.33±25.02</td>
<td>392.00±3.58</td>
<td>66.67±2.67</td>
<td>118.67±7.28</td>
<td>229.33±12.84</td>
<td>129.33±3.21</td>
<td>274.67±42.01</td>
<td>577.33±8.86</td>
</tr>
<tr>
<td>Thickness of white matter</td>
<td>77.33±7.64</td>
<td>184.00±30.85</td>
<td>474.67±9.83</td>
<td>52.00±4.00</td>
<td>116.00±16.23</td>
<td>336.00±8.26</td>
<td>48.00±3.82</td>
<td>62.67±16.83</td>
<td>142.67±13.28</td>
<td>78.67±1.33</td>
<td>184.00±29.14</td>
<td>485.33±15.27</td>
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<td>Width of ependymal layer</td>
<td>288.00±7.16</td>
<td>1018.67±240.98</td>
<td>1450.67±370.50</td>
<td>314.67±431.91</td>
<td>487.33±73.06</td>
<td>1057.33±30.11</td>
<td>237.33±7.64</td>
<td>296.00±5.47</td>
<td>1104.00±72.03</td>
<td>512.00±21.07</td>
<td>1224.00±227.02</td>
<td>1582.67±41.33</td>
</tr>
</tbody>
</table>

(Number of samples = 6)