RELATIONSHIP BETWEEN HEAD AND BRAIN PARAMETERS IN GOAT FOETUSES*

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Abstract

Growth dynamics of the head and brain were studied using 52 goat foetuses ranging from 1.4cm CRL (24 days of gestation) to 41.5cm CRL (full term). Head constituted almost one-half of the CRL during second month. Curved length of the cranium was greater than that of the face in all the age groups. Growth rates of 845.7 percent and 341.4 percent were recorded for cranial length and facial length, respectively during prenatal period. This indicated a faster growth of the cephalic region than the face during the foetal life. Curved and straight head lengths showed maximum correlation with the length of brain (r = 0.991 and 0.989, respectively). Regression equations derived from these can be used to predict the brain parameters from the head parameters during gestation. Unlike brain parameters, all the head parameters showed a greater increase during early gestation than in later stages. Calculated cephalic indices showed that in the first half of pregnancy, the foetal head was relatively shorter with a short facial region. In the second half, low cephalic indices indicated a comparatively narrower and relatively longer head.

Key words: *Growth, foetal head, brain, goat*

Studies on the head parameters as an index to endocranial volume have been reported by many workers in adult animals (Pampiglione, 1963; Moore, 1981; Sandhu and Dhingra, 1986; Malik *et al.*, 1989 ; Gupta and Sharma, 1990). However, literature on the relationship between the parameters of foetal head and brain is scanty in ruminants. These parameters are critical in understanding the normal and abnormal cephalic and encephalic growth. So this study was taken up to determine the relationship if any, between the size of the foetal head and the brain.

Materials and Methods

Prenatal development of brain was studied in foetal goats of different age groups. The gross body 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 the 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 separated at the occipito-atlantal junction and the following measurements were recorded. 1) Length of head - from the mid-point between the bases of the ears to the middle of the maxillary lip (straight and curved distances). 2) Length of cranium (neurocranial length) - from the mid-point between the bases of the ears to the mid-point between medial eye canthi (straight and curved distances). 3) Length of face

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(splanchnocranial length) - from the mid-point between medial canthi to the middle of maxillary lip. 4) Interauricular distance - transverse distance between the base of the ears. 5) Interorbital distance measured at two levels, as the transverse distance between the medial canthi (minimum interorbital distance) and transverse distance between the lateral canthi (maximum interorbital distance). 6) Transverse distance between dorsal commissures of nostrils. 7) Maximum cranial width (head width) – the transverse distance between the supraorbital processes of frontal bones (straight distance). 8) Intercornual distance – the transverse distance between the horn buds. 9) Intersupraorbital foramina distance. 10) Cranial height – the vertical distance between basioccipital and parietal bones. The cephalic index was calculated from the formula following Archana *et al.* (1998) for the yak,

$$\textbf{CEPHALIC INDEX} = \frac{\text{Head width}}{\text{Head length}} \times 100$$

The brain was then carefully dissected out and fixed in 10 percent neutral buffered formalin. The whole brain parameters, like length (the distance between the frontal pole of cerebral hemispheres and the rostral limit of origin of the first pair of cervical spinal nerves), width (maximum) and height (maximum at the level of parietal lobe of cerebral hemisphere) were measured. The data were analysed statistically (Snedecor and Cochran, 1985).

Table 1. Head parameters of goat foetuses at different ages (cm)

Head parameters (cm)	Brain weight (g)	Brain volume (ml)	Brain length (cm)	Brain width (cm)	Brain thickness (cm)	Body weight (g)	Age (days)	CRL (curved) (cm)	Total bent length (cm)
Head length (str.)	0.939	0.941	0.991	0.993	0.967	0.885	0.995	0.985	0.988
Head length (curved)	0.946	0.948	0.989	0.991	0.963	0.863	0.996	0.989	0.991
Head width (str.)	0.952	0.953	0.978	0.977	0.960	0.879	0.994	0.984	0.987
Cranial length	0.940	0.942	0.989	0.991	0.963	0.851	0.994	0.986	0.987
Facial length	0.948	0.950	0.982	0.983	0.955	0.879	0.991	0.986	0.989
Interauricular distance	0.957	0.957	0.952	0.944	0.911	0.925	0.965	0.964	0.973
Trans. Dist. bet. lateral canthi	0.925	0.927	0.970	0.975	0.965	0.849	0.976	0.968	0.969
Trans. Dist. bet. medial canthi	0.903	0.907	0.979	0.987	0.969	0.809	0.978	0.970	0.969
Trans. Dist. bet. cornual buds	0.903	0.904	0.943	0.947	0.947	0.824	0.966	0.949	0.950
Intersupraorbital foramina distance	0.928	0.930	0.974	0.982	0.973	0.844	0.985	0.976	0.976
Trans. Dist. bet. dorsal commissure of nostrils	0.950	0.952	0.987	0.984	0.956	0.875	0.988	0.984	0.987
Postr. height from foramen magnum	0.888	0.891	0.967	0.979	0.963	0.782	0.972	0.957	0.955

Results and Discussion

Head parameters of goat foetuses at different ages are given in table 1. Curved head length increased from 3.556 ± 0.264cm to 13.871 ± 0.390cm from second to fifth month. Head constituted almost one-half of the curved crown rump length (CRL) during second month. This agreed with the findings of Langman (1981), who reported that the head constituted approximately one-half of the CRL in human foetus by the beginning of the third month of gestation. Relation between age and the head parameters is shown in Fig. 1. Relationship between head length and selected body parameters at different stages of gestation is illustrated in Fig. 2. All the head parameters showed an increasing trend with the advancement of age. Curved length of the cranium was greater than that of the face in all the age groups. This may be due to the caudodorsal curvature of the head than the face. Langman (1981) opined that this was caused by the virtual absence of the paranasal sinuses and the small size of jawbones. Craniofacial ratios were 3.4:1, 2.6:1, 2.3:1 and 2.1:1 during second, third, fourth and fifth month, respectively. Parmar *et al.* (1997) reported that the approximate craniofacial length ratio was 2:1 during early, middle and

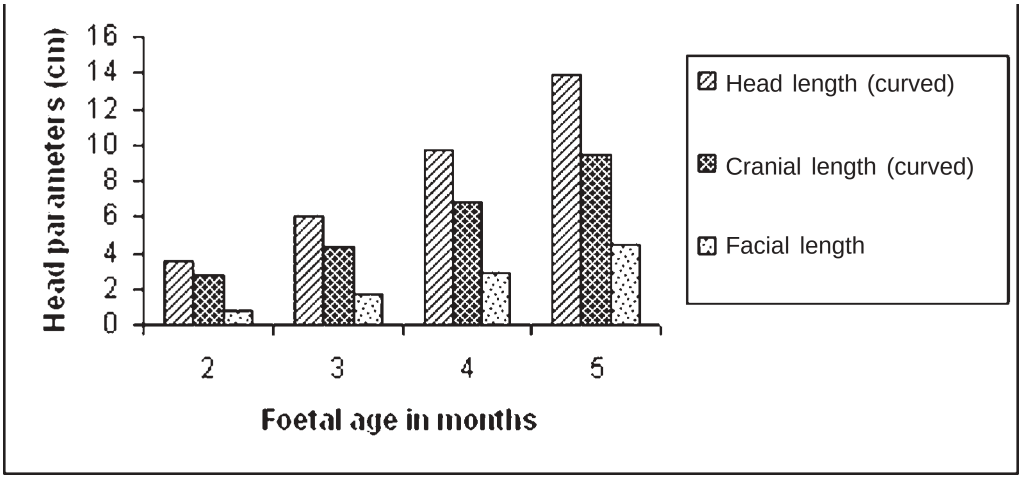

Fig 1. Relation between age and head parameters in goat foetuses

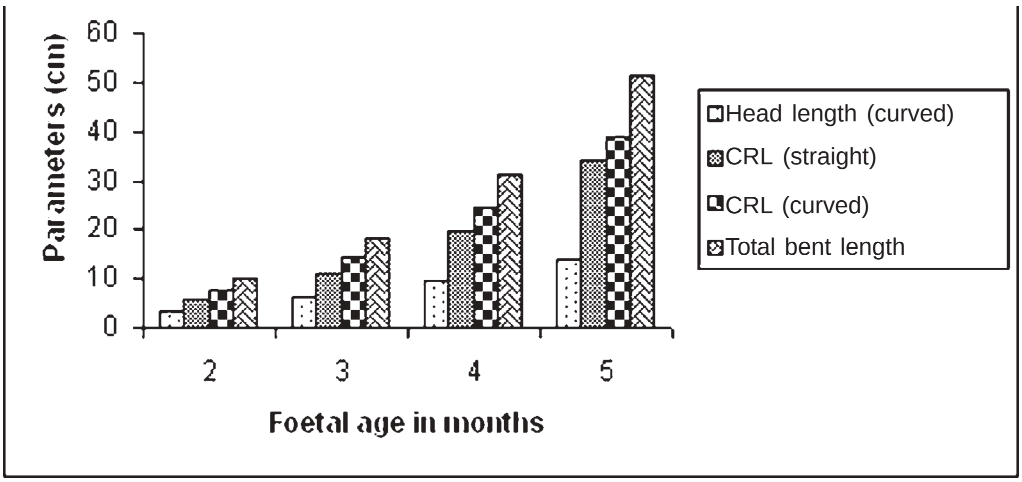

Fig 2. Relation between age and head parameters of head and body in goat foetuses

Table 2. Correlation coefficients (r) of head parameters on selected brain and body parameters

Parameters	2nd month (n=8)		3rd month (n=12)		4th month (n=10)		5th month (n=14)	
	Range	Mean± SE	Range	Mean± SE	Range	Mean± SE	Range	Mean± SE
Head length (curved)	2.500-4.500	3.556 ±0.264	4.700-8.200	6.018 ±0.372	9.000-10.200	9.720 ±0.136	11.800-16.200	13.871 ±0.390
Cranial length (curved)	2.200-3.200	2.750 ±0.134	3.300-5.900	4.343 ±0.258	6.500-7.100	6.790 ±0.074	2.200-10.800	9.457 ±0.223
Facial length (curved)	0.300-1.400	0.810 ±0.140	1.300-2.400	1.692 ±0.118	2.500-3.100	2.930 ±0.073	3.600-5.600	4.414 ±0.176
Interauricular distance	1.500-2.700	2.125 ±0.156	2.700-4.200	3.333 ±0.142	4.600-5.000	4.870 ±0.056	5.800-10.300	7.907 ±0.503
Transverse distance between lateral canthi	1.060-3.400	2.595 ±0.340	3.100-5.900	4.575 ±0.300	6.200-6.700	6.440 ±0.058	7.020-11.300	9.223 ±0.380
Transverse distance between medial canthi	0.700-1.500	1.150 ±0.112	1.500-2.700	2.003 ±0.121	3.600-3.920	3.853 ±0.031	3.940-5.800	4.963 ±0.163
Transverse distance between cornual buds	1.700-1.830	1.773 ±0.024	2.100-3.000	2.472 ±0.093	2.800-4.000	3.110 ±0.125	4.100-5.700	4.988 +0.127
Intersupraorbital foramina distance	0.500-1.100	0.829 ±0.088	1.000-1.800	1.383 ±0.085	1.900-2.200	2.007 ±0.038	2.300-3.400	2.879 ±0.098
Trans. dist. bet. dorsal commissure of nostrils	0.200-0.400	0.305 ±0.028	0.380-0.900	0.555 ±0.046	0.960-1.000	0.982 ±0.005	1.080-1.820	1.488 ±0.066

(All the 'r' values were significant at 1% level)

later stages of gestation in goat foetuses. A growth rate of 845.7 percent was recorded for cranial length during prenatal period. The corresponding value for facial length was 341.4 per cent. This indicates faster growth of cephalic region than the face during the foetal life. Trenouth (1984) reported that in human foetuses, the brain growth predominated over that of the face and showed a marked influence on the shape of head, particularly the cranium. Sarma *et al.* (2004) in their craniometrical studies on the skull of New Zealand White rabbit noticed that the neurocranium was much longer than the splanchnocranium in the adult animal.

Transverse distance between the lateral canthi was 1.2-1.4, 1.5-2.1, 1.7-2.3, 3.1-3.3 and 6.2-8.5 times of the distance between bases of ears, cornual buds, medial canthi, supraorbital foramina and nostrils, respectively during prenatal period. This was in accordance with the observations made by Parmar *et al.* (1997) in foetal goat. Correlation coefficients of head parameters on selected brain and body parameters are presented in table 2. Highly significant positive correlation was noticed between all these parameters. This revealed symmetrical growth of head and face regions. Trenouth (1984) found that the force vectors generated by the developing brain presumably change in relative magnitude and direction, so altering the equilibrium of the expanding forces applied to the cranium, thus accounting for the observed changes in shape of the cranium. Shape of the head was found to change progressively in all the three dimensions during foetal period. Curved and straight head lengths showed maximum correlation with the length of brain (r = 0.991 and 0.989, respectively). Regression equations derived from these are given in table 3. These can be used to predict the brain parameters from the head parameters during gestation. Thus it is possible to assess the normal growth rate of brain and cases of hypoplasia. Changes in the size and shape of cranial contents significantly modify the growth of functionally related tissues.

Unlike brain parameters, all the head parameters showed a greater increase during early gestation than in later stages. This is in agreement with the findings of Parmar *et al.* (1997) in goat foetuses. A similar trend in growth was reported for the different body measurements in goat (Malik *et al.*, 1989). The variation in growth rate during the developmental stages resulted in a symmetrical and proportionate growth of different structures of the head that are responsible for moulding the head into a wholesome normal shape and size, which is species dependent (Parmar *et al.*, 1997). Percentage contributions of curved head length to CRL (curved) were 46.12, 42.03, 40.05 and 35.66 percent during second, third, fourth and

Table 3. Regression equations for prediction of unknown brain parameters in goat foetuses

Predicted parameters (Y)	Known parameters (X)	Regression equations (Y = a + bX)
Brain length	Skull length	Y = 0.410+0.644X
Brain length	Neurocranial length	Y = 0.350+0.966X
Brain width	Transverse distance between lateral canthi	Y = 0.130+0.495X
Brain width	Transverse distance between medial canthi	Y = 0.350+0.872X
Brain width	Transverse distance between cornual buds	Y = 0.270+0.898X
Brain width	Intersupraorbital foramina distance	Y = 0.080+1.620X
Brain width	Skull width	Y = 0.150+0.869X
Brain thickness	Posterior height of skull	Y = 0.430+0.349X

fifth month of pregnancy, respectively. The gradual decrease in these data is due to a faster growth of the trunk in comparison to the head in order to accommodate the rapidly growing viscera for specific physiological needs to be performed after birth. All the head parameters showed highly significant correlation with CRL (curved) and total bent length of the foetus (Table 2). This shows that the head parameters contributed towards the body length and maintained the body symmetry. Parmar *et al.* (1997) found that the maximum symmetry of the body especially that of the head was attained in mid-gestation period, in goat.

Eventhough all the head parameters showed a greater increase during early gestation, the whole brain, cerebrum and cerebellum showed a spurt in their growth

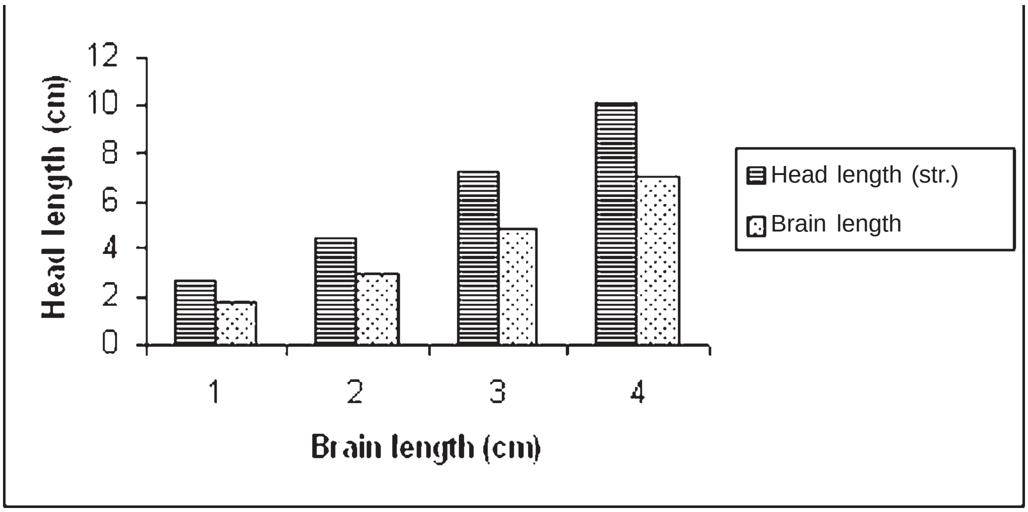

Fig 3. Relation between head length and brain length in goat foetuses

during the terminal stages of pregnancy. This explains the highly convoluted pattern of cerebral and cerebellar cortices in the animal. The convoluted cortex allows an increased surface area, so that more brain tissue can be accommodated in the available space.

Calculated cephalic indices were 60.78±1.91, 55.60±0.82, 50.85±0.54 and 53.92±0.57 percent during second, third, fourth and fifth month of gestation, respectively. This shows that in the first half of pregnancy, the foetal head was relatively short with a short facial region. In the second half, low cephalic indices indicated a comparatively narrower and relatively longer head. Gupta and Sharma (1990) reported that the cephalic index of adult bovine skull was 52.14±3.10 percent. In adult rabbit, the value was 54.89±0.62 percent (Sarma *et al.*, 2004), whereas in adult Indian yak, it was 64.12±3.77 percent (Archana *et al.*, 1998). Relationship between straight head length and brain length during various stages of gestation is shown in Fig. 3. The difference between these mean values increased during gestation due to the lengthening of the facial region towards the second half of gestation.

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