



Prenatal Development of Heart of Goat (*Capra hircus*): Morphometric Observations

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ABSTRACT

The study was conducted on 28 foetal hearts of goats of non- descript breed. These were grouped as; Group-I (early prenatal period; ≤ 50 days of gestation), Group-II (mid prenatal period; between ≥ 51 days to ≤ 100 days of gestation) and Group III (Late prenatal period; of ≥ 101 days age till parturition). There were 12 foetii in II and III- group but only four foetii in group-I. The age of goat foetii was estimated by using the standard formula of Hugget and Widas (Singh *et al.* 1979). The weight and volume of the heart increased continuously from 46th to 148th day of gestation in a colinear fashion, however the maximum gain in weight and volume occurred during the late prenatal period. The percent of heart weight to the body weight goes on reducing with the advancement of age of foetus. During early prenatal period the heart was wider (cardiac shape index 80) while in late prenatal period it was longer (cardiac shape index 65.5) in shape.

Keywords: Prenatal, development, heart, goat

Prenatal development of heart has been described in varying details in domestic animals' and human embryos (Patten, 1948; Arey, 1954; Noden and Lahunta, 1985). Marrable (1971) illustrated the chronological sequence of development of heart in pig. Gupta *et al.* (2014) reported the embryonic development of heart of Indian buffalo. But reports on the prenatal development of heart in goat are not traceable. Therefore the present study has been taken up to generate the basic morphometric data on the developing heart of prenatal goat.

MATERIALS AND METHODS

The study was conducted on the 28 hearts of foetii of goats of non- descript breed. The samples were collected from the local slaughter houses, farms and Veterinary College Clinical complex at Mathura. The approximate age of goat foetii was estimated by using the standard formula of Hugget and Widas as interpolated by Singh *et al.* (1979) ($3\sqrt{\text{wt. of foetus in gm}/0.096+30}$). The foetii were divided into three groups viz; Group- I (early prenatal period;

≤ 50 days of gestation), Group-II (mid prenatal period; between ≥ 51 days and ≤ 100 days of gestation) and Group III (Late prenatal period; from ≥ 101 days till parturition). Group I comprised of 4 foetii whereas, Group II and III comprised of 12 foetii in each group. The foetii of Group-I aged beyond 42 days of gestation, Group II and Group III were dissected carefully for topographical study and then exteriorized from the thorax. Various biometrical parameters (Table 1) of heart were then recorded with the help of digital Vernier Calipers and non- stretchable thread. The weight of heart was taken on the electronic weighing balance. The volume of heart was estimated by water displacement method in the graduated cylinder. The data were subjected to standard statistical analyses (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

The biometric data on the mean weight of embryo, weight of heart (with and without pericardium), volume of heart (with and without pericardium), maximum length, width

(lateromedial), thickness (craniocaudal), circumference at the base, distance between the apex of right and left ventricles, length of cranial and caudal borders, length and width of both the atria and ventricles have been recorded on the heart of 46 to 148 days old goat fetuses and have been summarized (Table 1).

Data in group-I (early prenatal period) included mensurations of the heart parameters of four foetuses of 46, 47, 48 and 49 days of gestation only; the data of group-II and group-III included the observations on the heart of foetuses from 51 to 100 and 101 to 148 days of gestation respectively. The embryos and more particularly their hearts were too small to be used for the gross dissection and biometrical data generation before 46 days of gestation and hence have not been included in this study.

Weight of embryo

In early prenatal period (Group-I), the average weight of embryos (between 46-50 days age) was 4.752 ± 0.653 g, while the total weight gain during the period was 3.113g and the average weight gain per day was 1.038g. During mid prenatal period the average weight of embryo was 110.32 ± 26.119 g with a minimum of 8.013g on 51st day and maximum of 290.69g on the 99th days of gestation showing a continuous growth from the 51st day through 99th day of gestation. The total weight gain during the period was 282.677g and the average weight gain per day was 5.889g. In late prenatal period (group-III) the average weight of embryo was 706.15 ± 113.602 g. It grew to 1455.60g on 148th day of gestation from 312.50g on 101st day of gestation, thereby registering a total growth of 1143.10g with an average daily gain in weight of 24.321g. Thus the data revealed a continuous linear increase in the weight of embryo with the advancement of the gestation period. It further showed that maximum gain in the weight of embryo occurred during the late phase of life.

Weight of heart with pericardium

In early prenatal period the average weight of heart with pericardium was 0.076 ± 0.008 g with a minimum value of 0.056g on 46th day and maximum value of 0.094g on 49th day of gestation with an average daily weight gain of 0.013g. In the mid prenatal period the average weight of heart with pericardium was 1.18 ± 0.26 g with a minimum

of 0.15g on 51st day and 2.97g on 99th day of gestation. The weight of heart increased continuously and the average per day weight gain of heart with pericardium was 0.06g. In the late prenatal period the average weight of heart with pericardium was 6.433 ± 0.938 g (Table 1) with a minimum of 2.39g (on 101 day) and the maximum of 12.00g (on 148th day). The average weight gain per day was 0.20g. Data indicated that there was maximum gain in weight of the heart with pericardium during the late prenatal period.

Volume of heart with pericardium

The average value for the volume of heart with pericardium was 0.078 ± 0.009 cm³, 1.178 ± 0.254 cm³ and 6.405 ± 0.900 cm³ for group-I, group-II and group-III, respectively (Table 1). The average per day gain in volume of heart was 0.013 cm³ in group-I, 0.05 cm³ in group-II and 0.19 cm³ per day in group-III. Thus the data revealed that in late prenatal period the volume of heart along with pericardium increased significantly in comparison to early and mid prenatal periods.

Weight of heart (without pericardium)

In early prenatal period the average weight of heart was 0.071 ± 0.006 g (Table 1) with a minimum value of 0.055 g on 46th day and maximum value of 0.085 g on 49th day of gestation. In mid prenatal period the average weight of heart was 1.00 ± 0.22 g with a minimum of 0.14g on 51st day and 2.48g on 99th day of gestation. In the late prenatal period the average weight of heart was 5.50 ± 0.80 g with a minimum of 2.18g and the maximum of 10.37g on the 101st and 148th days of gestation, respectively. The average gain in weight of heart without pericardium per day was 0.010, 0.05 and 0.17g in group-I, group-II and group-III respectively. Data indicated that there was maximum gain in the weight of heart during the late prenatal period of foetus.

Volume of heart (without pericardium)

The average volume of heart in group-I, group-II and group-III were 0.068 ± 0.01 cm³, 1.13 ± 0.27 cm³ and 5.73 ± 0.80 cm³, respectively (Table 1). In the late prenatal period the volume of heart increased more significantly in comparison to early and mid prenatal periods.

Table 1: Weight of embryo and external biometric parameters of heart (Mean \pm SE) in prenatal goat

Parameters	Group-I	Group-II	Group-III
Weight of embryo (g)	4.752 \pm 0.653	110.32 \pm 26.11	706 \pm 113.602
Weight of heart with pericardium (g)	0.076 ^a \pm 0.008 (0.06-0.09)	1.178 ^a \pm 0.260 (0.15-2.97)	6.433 ^b \pm 0.938 (2.39-12.00)
Volume of heart with pericardium (cc)	0.078 ^a \pm 0.009 (0.06-0.11)	1.178 ^a \pm 0.254 (0.14-2.75)	6.405 ^b \pm 0.900 (2.50-11.50)
Weight of heart (without pericardium) (g)	0.071 ^a \pm 0.006 (0.06-0.09)	0.996 ^a \pm 0.217 (0.14-2.48)	5.500 ^b \pm 0.796 (2.18-10.37)
Volume of heart (without pericardium) (cc)	0.068 ^a \pm 0.006 (0.05-0.08)	1.133 ^a \pm 0.267 (0.14-3.00)	5.727 ^b \pm 0.799 (2.20-10.50)
Length of heart (mm)	6.35 ^a \pm 0.23 (5.78-6.47)	14.87 ^b \pm 1.32 (8.00-22.56)	28.34 ^c \pm 1.53 (19.00-36.60)
Width of heart (mm)	5.08 ^a \pm 0.21 (4.61-5.61)	10.44 ^b \pm 0.84 (6.30-15.00)	18.29 ^c \pm 0.63 (14.15-21.28)
Thickness of heart (mm)	4.02 ^a \pm 0.22 (3.50-4.58)	9.00 ^b \pm 0.78 (5.20-13.88)	17.62 ^c \pm 1.17 (11.99-24.90)
Circumference at base (mm)	16.25 ^a \pm 0.85 (14.00-18.00)	33.00 ^b \pm 2.52 (20.00-46.00)	58.88 ^c \pm 2.57 (45.00-73.00)
Cranial border length (mm)	5.14 ^a \pm 0.30 (4.30-5.75)	15.22 ^b \pm 1.58 (7.01-23.59)	28.78 ^c \pm 1.67 (20.00-37.89)
Caudal border length (mm)	4.41 ^a \pm 0.26 (3.87-5.10)	10.98 ^b \pm 0.99 (5.67-16.66)	20.88 ^c \pm 1.48 (13.50-30.45)
Distance b/w apex of right and left ventricles (mm)	0.67 ^a \pm 0.10 (0.43-0.85)	2.18 ^b \pm 0.25 (0.67-3.46)	4.87 ^c \pm 0.34 (2.87-6.40)
Length of right atrium (mm)	2.19 ^a \pm 0.31 (1.72-3.05)	4.36 ^b \pm 0.28 (2.78-5.90)	8.80 ^c \pm 0.52 (6.81-11.90)
Width of right atrium (mm)	3.62 ^a \pm 0.239 (3.00-4.07)	8.18 ^b \pm 0.54 (5.00-11.02)	13.35 \pm 0.62 (9.56-17.53)
Length of left atrium (mm)	3.21 ^a \pm 0.393 (2.65-4.34)	6.56 ^b \pm 0.45 (3.96-8.84)	11.40 ^c \pm 0.53 (7.13-13.89)
Width of left atrium (mm)	3.26 ^a \pm 0.31 (2.65-3.80)	7.93 ^b \pm 0.60 (5.00-10.47)	13.00 ^c \pm 0.53 (8.48-14.79)
Length of right ventricle (mm)	3.29 ^a \pm 0.25 (2.78-3.86)	8.10 ^b \pm 0.704 (4.69-12.00)	15.79 ^c \pm 0.97 (10.91-21.72)
Width of right ventricle (mm)	4.11 ^a \pm 0.12 (3.80-4.32)	9.20 ^b \pm 0.84 (4.67-13.61)	16.50 ^c \pm 0.69 (12.41-20.00)
Length of left ventricle (mm)	4.78 ^a \pm 0.261 (4.02-5.21)	11.82 ^b \pm 1.19 (5.90-19.66)	23.18 ^c \pm 1.25 (16.09-32.20)



Width of left ventricle (mm)	3.19 ^a ± 0.05 (3.08-3.28)	7.03 ^b ± 0.64 (3.59-10.58)	12.86 ^c ± 0.48 (9.66-15.16)
Heart Percent weight in relation to thoracic organs	2.95 ^a ± 0.12 (2.66-3.26)	3.89 ^b ± 0.14 (3.03-4.82)	4.23 ^b ± 0.12 (3.48-4.97)
Heart weight percent (with pericardium) in relation to body weight	1.62 ^c ± 0.08 (1.45-1.83)	1.22 ^b ± 0.08 (0.95-1.81)	0.93 ^a ± 0.032 (0.77-1.10)
Heart weight percent (without pericardium) in relation to body weight	1.53 ^c ± 0.09 (1.31-1.71)	1.04 ^b ± 0.08 (0.75-1.76)	0.80 ^a ± 0.03 (0.70-0.98)
Cardiac shape index	80.00 ^b ± 0.02 (74.0-84.0)	71.00 ^a ± 0.02 (60.0-80.0)	65.70 ^a ± 0.03 (52.0-85.0)

N (Number of foetuses) = 4 in Group-I, 12 in Group-II and 12 in Group-III; The value in parenthesis indicate range; a, b and c show the significant difference between the groups at 5% probability level.

Heart weight % of body weight

The heart weight percentage was estimated against the body weight. The data revealed a relatively higher percent (1.53%) weight of heart in relation to body weight during the early prenatal period. The average ratio was reduced abruptly in the mid prenatal period (1.04%) and was further reduced in the late prenatal period (0.80%). Thus the data indicated that the percent weight of heart weight when compared to the whole body weight goes on reducing with the advancement in the age of gestation i.e. the whole body grew at a much faster pace than the heart as a single organ.

Length of heart

The data on length of heart showed a total increase of 0.96 mm between 46th to 49th day of gestation with an average gain in the length of 0.32 mm per day in group-I. During the mid prenatal period the minimum length of heart measured 8.00 mm on 51st day and maximum 22.56 mm on 99th day of gestation. There by indicating a growth of 0.303 mm per day (increase in length). In late prenatal period there was an increase of 0.375 mm per day i.e per day increase in length of heart was slightly higher during the late prenatal period. The data followed the trend of the growth of weight of heart.

Width (lateromedial diameter) of heart

The width of heart of goat foetuses from 46th -148th days

of gestation depicted a progressive increase. The average width of heart of group-I was 5.075 ± 0.21 mm (Table 1). Per day increase in width was 0.25 mm. In group-II the average width measured 10.44 ± 0.84 mm. The total growth in width between 51-99 days was 8.7 mm with an average increment of 0.18 mm per day. The average width in group-III was 18.29 ± 0.63 mm. The average increase in width per day in this group was 0.10 mm.

The data revealed comparatively a much wider heart at the end of early prenatal period. The rate of growth of lateromedial width on per day basis reduced in group-II and was least in group-III due to differential development of auricles and ventricles and rotation of aorta and pulmonary trunk at the base in order to take up their definitive form and function post partum.

Thickness (craniocaudal diameter) of heart

In group-I the average thickness of heart was 4.018 ± 0.22 mm with a range of 3.50 mm-4.58 mm (Table 1). In group-II it was 9.00 ± 0.78 mm with a minimum (5.20 mm) on 51st day and maximum (13.88) on 99th day of gestation. In group-III the average thickness was 17.62 ± 1.17 mm with a maximum (24.90 mm) on 145th day and minimum (11.99 mm) on 102nd day of gestation. In group-I a total increase in thickness was 0.56 mm with an average per day increment of 0.187 mm. In group-II total increase in thickness was 8.68 mm with per day increase of 0.181 mm. In group-III total increase in thickness was 12.56 mm with per day increase of 0.27 mm. The data revealed significant

growth in the thickness of heart in the late prenatal period than in the mid and early prenatal periods, thus indicating a much thicker heart in group-III.

Circumference of heart (at the base of the ventricles)

The average circumference of the heart was 16.25 ± 0.85 mm, 33.00 ± 2.52 mm and 58.88 ± 2.57 mm for group-I, group-II and group-III, respectively (Table 1). The per day increase in the circumference was 1.00 mm, 0.54 mm and 0.60 mm for group-I, II and III, respectively. In group-II the minimum circumference (20 mm) was recorded on 51st day and maximum (46 mm) on 99th day of gestation. In group-III the minimum and maximum circumference was 45 mm and 73 mm on 101 and 145 days of gestation respectively. The data revealed a continuous and almost comparable average daily growth in the circumference of heart during mid and late prenatal periods.

Cranial border length

In group-I the minimum length of cranial border was recorded on 46th day and maximum on 49th day with an average per day growth of 0.483 mm. The overall mean length of cranial border of heart was 5.135 ± 0.30 mm during early prenatal period of embryo (Table 1). During mid prenatal period the average measurement of the cranial border was 15.22 ± 1.58 mm. It grew at an average rate of 0.345 mm per day. In late prenatal period, the average length of cranial border of heart was 28.78 ± 1.67 mm. The total growth during this period was 17.89 mm and the average growth rate was 0.381 mm per day. The data revealed >3 times growth in length of cranial border of heart through group-I to group-II and approximately 2 times growth from group-II to group-III. However, the growth was regular and positive from 46th to 148th day of gestation.

Caudal border length

The average length of the caudal border of heart measured 4.405 ± 0.26 mm in group-I (Table 1) with a growth rate of 0.41 mm per day. In the mid prenatal period average length of caudal border of heart was 10.98 ± 0.99 mm. The average growth rate per day was 0.229 mm. In the late prenatal period the average length of caudal border of heart was 20.88 ± 1.48 mm and the average growth

rate was 0.361 mm per day. The data thus revealed approximately 2.5 times increase in the length of caudal border of heart through group-I to group-II and 2 times increase during group-II to group-III, the growth being continuous from day 46th to 148th day of gestation. The data further revealed that the pattern of growth of caudal border of heart followed the trend of growth of cranial border.

Distance between the apex of right and left ventricles

In group-I the average distance between the apex of right and left ventricles was 0.67 ± 0.10 mm (Table 1). In group-II the minimum distance between the apices of two ventricles was recorded (0.67 mm) on 51st day and the maximum (3.46 mm) on 99th day of gestation with the average distance of 2.18 ± 0.25 mm. However, in the group-III the average distance was 4.87 ± 0.34 mm, with a minimum of 2.87 mm on 107th day and maximum of 6.40 mm on 131st day of gestation. The average per day increase in the distance between the apex of right and left ventricles in group-I was 0.14 mm, in group-II it was 0.06 mm (Table 4) and in group-III 0.05 mm. It indicated that the distance between the apices of right and left ventricles decreased in group-I to group-II and maintained in group-III; revealing a coordinated parallel growth of two ventricles.

Length of right atrium

In early prenatal period, the average length of right atrium was 2.188 ± 0.305 mm, in mid prenatal period 4.363 ± 0.28 mm and in late prenatal period 8.799 ± 0.521 mm. The average per day increase in the length of right atrium was not regular in group-I, but in group-II and group-III it showed an increase of 0.05 and 0.08 mm per day, respectively. It was revealed that although the length of right atrium increased from group-I through group-II but it was at a faster pace in the later phase of prenatal life.

Width of right atrium

In early prenatal period the average width of right atrium was 3.620 ± 0.24 mm, in mid prenatal period 8.18 ± 0.54 mm, and in late prenatal period 13.35 ± 0.62 mm. The data revealed that the width of right atrium increased approximately 2.5 times from group-I to group-II and approx. 1.5 times from group-II to group-III, pointing



towards a slower rate of growth of width of right atrium in the later phases of gestation.

Length of left atrium

The average length of left atrium measured 3.21 ± 0.39 mm in group-I, 6.56 ± 0.45 mm in group-II and 11.40 ± 0.53 mm in group-III (Table 1). The data revealed that the length of left atrium increased approx. 2 times from group-I to group-II and around 1.5 times from group-II to group-III, thus followed the trend of overall growth of heart length

Width of left atrium

The average width of left atrium measured 3.258 ± 0.31 mm in group-I, 7.93 ± 0.60 mm in group-II and 13.00 ± 0.53 mm in group-III (Table 1). The data revealed that the width of left atrium increased approx. 2.5 times from group-I to group-II and approx. 1.5 times from group-II to group-III. The observation completely followed the trend of growth of the right atrium.

Length of right ventricle

In early prenatal period the average length of right ventricle was 3.288 ± 0.25 mm, in mid prenatal period 8.10 ± 0.70 mm and in late prenatal period 15.79 ± 0.97 mm (Table 1). The data revealed an approx. 2.5 times increase in the length of right ventricle from group-I to group-II and approx. 2 times increase from group-II to group-III.

Width of right ventricle

In early prenatal period the average width of right ventricle was 4.113 ± 0.12 mm, in mid prenatal period 9.20 ± 0.84 mm and in late prenatal 16.50 ± 0.69 mm (Table 1). The data showed an increase of approx. 2.2 times in the width of right ventricle from group-I to group-II and 1.7 times from group-II to group-III.

Length of left ventricle

In early prenatal period the average length of left ventricle was 4.78 ± 0.26 mm, in mid prenatal period 11.82 ± 1.19 mm and in late prenatal period it was 23.18 ± 1.25 mm (Table 1). The pattern of increase in the length of left

ventricle followed the trend of increase in length of right ventricle.

Width of left ventricle

In early prenatal period the average width of left ventricle was 3.185 ± 0.05 mm, in mid prenatal period 7.03 ± 0.64 mm and in late prenatal period 12.86 ± 0.48 mm (Table 1). The data followed the trend of increase in width of left ventricle and also of the width of right ventricle.

Percent weight of heart vs percent weight of total thoracic contents

The mean percent weight of whole organs present in the thoracic cavity was 2.95 ± 0.12 , 3.89 ± 0.14 and 4.23 ± 0.12 in foetuses of group-I, group-II and group-III, respectively. On the other hand the mean percent weight of heart compared to all viscera was 1.53 ± 0.09 , 1.04 ± 0.08 and 0.80 ± 0.03 for group-I, group-II and group-III, respectively (Table 1). Data indicated that the thoracic cavity, which was initially occupied mainly by the heart in foetuses of group-I, enlarged in size in the foetuses of group-II and III with the advancement of age, but the growth of other thoracic organs (mainly lungs) occurred much faster than the heart in fetuses of the later age groups. Hence the heart weight percent in relation to thoracic organs decreased with the advancement of the age of foetus. It became minimum (18.81%) in late prenatal period, while it was intermediate (26.72%) in the mid prenatal period and maximum (51.73%) in early prenatal period.

The close perusal of data finally revealed that the weight and volume of heart increased from 46th to 148th days of gestation continuously and regularly in a co-linear fashion however the maximum gain in weight and volume of heart occurred during the late prenatal period. As far as the heart weight percent of total body weight was concerned, the percent heart weight goes on reducing with the advancement of age. It was 1.53% in early prenatal period, whereas in late prenatal period it formed only 0.80% of body weight. Sisson (1953) described that the heart formed 0.4 to 0.5 percent of body weight in adult ox, 0.7% in horse and 1% in dog. The size of heart varied considerably among species, breeds, individuals, age and condition of animals; and it constituted about 0.75% of

the body weight in domestic animals (Dyce *et al.*, 2002; Konig and Liebich, 2007) and 0.76% in cattle (Szuba *et al.*, 1986).

The per day increase in length of heart was maximum (0.375 mm) during late prenatal period whereas per day increase in the width of heart was more (0.25 mm) during early prenatal period. Therefore the heart was wider during early prenatal period but with the advancement of age, it became more longer than wider. The data were further supported by the cardiac shape index which was 80.0, 71.0 and 65.5 in early, mid and late prenatal periods, respectively. The per day increase in the thickness of heart was almost same during early (0.187 mm) and mid prenatal (0.181 mm) periods, but in the late prenatal period it was maximum (0.27 mm). The average circumference of heart at the base was 16.25 mm in early prenatal period, which increased more than two times from group-I to group-II and less than 2 times from group-II to group-III. The per day increase in the circumference was maximum (1.00 mm) in early prenatal period followed by late prenatal period (0.60 mm). Therefore it might be concluded that circumference of heart was mainly contributed by its width in early prenatal period, but in late prenatal period it was its thickness. However, there was continuous and almost comparable daily growth in circumference of heart during mid and late prenatal periods. The increase in the length of cranial and caudal borders of heart was regular and positive from 46th to 148th day of gestation. The growth of caudal border of heart followed the trend of growth of cranial border; however the cranial border increased more in length than the caudal border. Therefore the cranial border of heart was strongly convex throughout the gestation and the caudal border was nearly straight in goat fetuses. Same has also been reported by Sisson (1953) in adult equines, Raghavan (1964) in ox and Malik *et al.* (1999) in deer. The width of right and left atrium increased 2.5 times from group-I to group-II and 1.5 times from group-II to group-III, thus indicated similar trend of growth in the size of left and right atria. However the growth was faster during early to mid prenatal period. The increase in length of right ventricle was 2.5 times from group-I to group-II and 2 times from group-II to group-III. Similarly the increase in the width of right ventricle was 2.2 times from group-I to group-II and 1.7 times from group-II to group-III. The increase in the length and width of left atrium followed the same trend as of the right ventricle. The growth of ventricle

was faster during early to mid prenatal period. From the analysis of data it is further revealed that the size of left atrium and ventricle was more than the size of right atrium and ventricle throughout the gestation period. The heart weight percent in relation to thoracic organs decreased with the advancement of age as it was minimum (18.81%) in late prenatal period, while intermediate (26.72%) in mid prenatal period and maximum (51.73%) in early prenatal period. This study also finds support by Marrable's (1971) findings.

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