

Ultrasonic Measurement of Fetal Parameters for Estimation of Gestational Age in Korean Black Goats

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ABSTRACT. The objective of this study was to determine relationship of gestational age with measurement of diameter of head, orbit, trunk, long and short axis of heart, aorta, placentome, umbilical cord and umbilical vein in Korean black goats. In this study, ten pregnant Korean black goats (*Capra hircus aegagrus*) were used. Pregnancy diagnosis was performed with a 5 MHz linear transducer and ultrasonographic scan were performed at 60, 75, 90, 105, 120 and 135 days after mating with a 4–9 MHz convex transducer. For accurate measurement, all fetal organs were measured at least 3 times. The diameter of head, orbit, trunk, long and short axis of heart, aorta, placentome, umbilical cord and umbilical vein were significantly increased with the gestational age ($P < 0.05$). Of these parameters, trunk ($r = 0.8876$; $p < 0.001$), long axis of heart ($r = 0.9168$; $p < 0.001$) and short axis of heart ($r = 0.8819$; $p < 0.001$) proved to be the more effective measurements than other parameters, as it correlated well with gestational age. Results indicate that ultrasonic measurements of these parameters were useful methods to estimate gestational age in Korean black goat.

KEY WORDS: fetal parameter, gestational age, Korean black goat, ultrasonography.

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The accurate estimation of fetal age is important for appropriate prenatal management. The estimation of gestational age by ultrasound is based on the known relationship fetal age and size [21]. Estimation of the gestational age of fetuses would be useful in specific clinical, management, or research applications [5]. For example, it is useful monitoring of status of fetus and mother, clinical problems such as restriction of fetal development, or missed observation of breeding time. The ultrasonic measurement of biparietal diameter is routinely measured during human prenatal examinations [7, 21]. Recently, abdominal circumference, orbit, lens and heart were also estimated by ultrasonic scanning and relation between these and fetal growth were worked [4, 11, 15, 21].

Estimation of gestational age by ultrasound was also applied to the animals in the several studies. Sabbagha *et al.* [18] reported the change of the biparietal diameter during pregnancy in the rhesus monkey. Luvoni *et al.* [14] evaluated biparietal diameter, gestational sac and placental thickness for estimation of gestational age in the bitch. White *et al.* [22] reported the relation of biparietal diameter, trunk diameter, crown-rump length and uterine diameter with gestational age in the cattle. These studies were also reported in the small ruminants. In sheep [1, 5, 10, 12, 16], goat [8–10, 17] and red deer [2, 23], relationship between biparietal diameter and gestational age was reported. Additionally, in the sheep and goat, gestational age was also estimated by diameter of fetal trunk [1, 10, 16] and placentome [10, 12] using ultrasound.

In Korea, goats are neither a predominant livestock species nor a popular laboratory model. However, Korean black goats (*Capra hircus aegagrus*) are very useful as experimental animals for transgenic animal studies because they have not only a gentle and a short generation time, but also low costs and produce large milk compared with their size. Reproductive characteristics of Korea black goats was average 1–3 litter size, average 1.5 parity per year and estrus was shown with the exception of summer. Therefore, many of studies have been reported using the Korean black goat for adequate reproductive management [13, 20]. However, there were few studies on the assessment of fetal age by means of the ultrasonic scanning in the Korean black goats [19].

The objective of this study was to determine the relationship of gestational age with measurement of diameter of fetal head, orbit, trunk, long and short axis of heart, aorta, placentome, umbilical cord and vein in Korean black goat.

MATERIALS AND METHODS

Experimental animals: Ten pregnant Korean black goats (*Capra hircus aegagrus*) were used in this study. The does of body weight from 15 to 25 kg were fed alfalfa/grass hay and commercial ration with free access to water and trace-mineralized salt.

Pregnancy diagnosis: Transrectal ultrasonographic examination with 5 MHz linear array transducer (Sonoace 600[®], Medison Co., Seoul, Korea) was performed in female Korean black goats between Day 30 to 45 post mating (breeding day=0). The animals were restrained in standing position during examination with closing the eyes using towel. The feces in the rectum were cleared, and some

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lubricant was infused into the rectum. The transducer was introduced into the rectum until the bladder was displayed on the screen. The entire uterine horns were observed cranial to the bladder. When multiple fluid-filled uterine, embryo proper or fetal heartbeat was detected, doe was diagnosed as pregnant.

Ultrasonographic measurement: Transabdominal ultrasonographic examination was done at 60, 75, 90, 105, 120 and 135 days after breeding. A commercially available SA 8800® (Medison Co. Seoul, Korea) with 4–9 MHz convex transducer was used to measure the diameter of the head, orbit, trunk, long and short axis of heart, aorta, placentome, umbilical cord and umbilical vein of the fetus. After clipping the hair of lower abdomen, ultrasonographic scans were performed with the goats in dorsal recumbent position which reduced maternal movements by manual restrain and allowed improved imaging.

Diameter of fetal head: In the measurement of diameter of fetal head, image symmetry is essential to accurate measurement. The presence of both fetal orbits in the same image is an excellent symmetry reference prior to freezing the image showing greatest head width. The diameter of fetal head was measured from images in which the axis of head symmetry was perpendicular to the ultrasound beam (Fig. 1a).

Diameter of fetal orbit: The diameter of fetal orbit was assessed from lateral view of head, when it was rounded and maximal size. The vertical and horizontal diameters were measured with electronic calipers and then mean diameter of fetal orbit was calculated (Fig. 1a). Video recording for retrospective analysis was used for accurate measurement.

Diameter of fetal trunk: The diameter of fetal trunk was measured as the largest cross-sectional diameter of the abdomen at the level of the junction of the umbilical vein (Fig. 1b). Transsectional fetal body was round shape, diameter was measured with integral electronic calipers.

Long and short axis of heart: The long and short axis of the heart were measured from a transverse section of the four chamber view at diastolic state during a period of absent fetal body movement (Fig. 1c). Video recording for retrospective analysis was also used for accurate measurement.

Diameter of aorta: The wave of artery was observed by pulse wave Doppler and the diameter of aorta was measured from a transverse section of the long axis LV outflow view during a period of absent fetal body movement (Fig. 1d). We measured the diameter of aorta after observation of at least 1 min. After measuring the maximum diameters of aorta at least 3 times, we determined the diameter of aorta as average of 3 values.

Diameter of placentome: As pregnancy progresses, the concave circular shape of the small ruminant placentome results in C-shaped or O-shapes gray images, depending on plane of section, against the black uterine fluid. Usually, a lot of the placentome was viewed on the same image (Fig. 1e). In this study, we measured at four big sizes of placentomes and then mean diameter of those placentomes was calculated.

Diameter of umbilical cord and vein: When the fetal body and the umbilical cord were seen in the screen at the same time, the diameter of umbilical cord was measured at two places which are entrance of body and 1 cm apart from entrance by the integral electronic calipers, and then the mean diameter of umbilical cord was calculated. The umbilical vein was sampled at the nearest part of fetal umbilical cord to allow for any minor differences in diameter along the cord. The internal diameter of the umbilical vein was measured by obtaining perpendicular view of the cord at maximum magnification followed by caliper placement at the inner edge of the vessel (Fig. 1f). Diameter of umbilical cord and vein was also determined as average after measured the maximum diameter at 3 times.

Statistical analysis: The relationships between gestational age and each parameter of the ultrasonic measurements were plotted as linear regressions and expressed as straight-line equations using SigmaPlot 2000 (SPSS Inc., Illinois, U.S.A.). Data of this study fitted to their optimal regression line ($p < 0.05$) and described by the equation as well as the coefficient of determination was calculated.

RESULTS

The results of measurements of head, orbit, trunk, long and short axis of heart, aorta, umbilical cord and vein by ultrasound at a different gestational age (60, 75, 90, 105, 120 and 135 days) in Korean black goat were shown Table 1. And, the linear regression curves (Fig. 2) were calculated from the data as a function of gestational age.

Correlations between measurement of parameters and gestational age: Coefficient values of each parameter were shown Table 2. There were highly significant correlations ($p < 0.001$) between gestational age and three parameters including with long axis of heart ($r = 0.9168$), short axis of heart ($r = 0.8819$) and trunk ($r = 0.8876$). Relatively high correlations ($p < 0.05$) were also evident in fetal head ($r = 0.8089$), orbit ($r = 0.8737$) and aorta ($r = 0.8507$).

Estimation of gestational age from ultrasound measurements: Equations for estimation of gestational age from ultrasound measurements are presented in Table 2 and Fig. 2. As shown in Table 2, the equation for estimating gestational age by long axis of heart ($y = 22.0779x + 45.8732$; Fig. 2d), short axis of heart ($y = 32.0683x + 45.2564$; Fig. 2e) and trunk ($y = 13.2648x + 33.7059$; Fig. 2c) had the higher coefficient of determination than other parameters. Additionally, the equations for estimating gestational age by head ($y = 21.3110x + 30.3119$; Fig. 2a), orbit ($y = 60.9832x + 10.4719$; Fig. 2b) and aorta ($y = 151.1366x + 37.4774$; Fig. 2f) were also effective at predicting gestational age. However, estimating gestational age by placentome was not appropriate its low coefficient values ($y = 26.5182x + 42.2374$ [$r = 0.5740$]; Fig. 2g).

DISCUSSION

In the present study, fetometry by real-time ultrasound

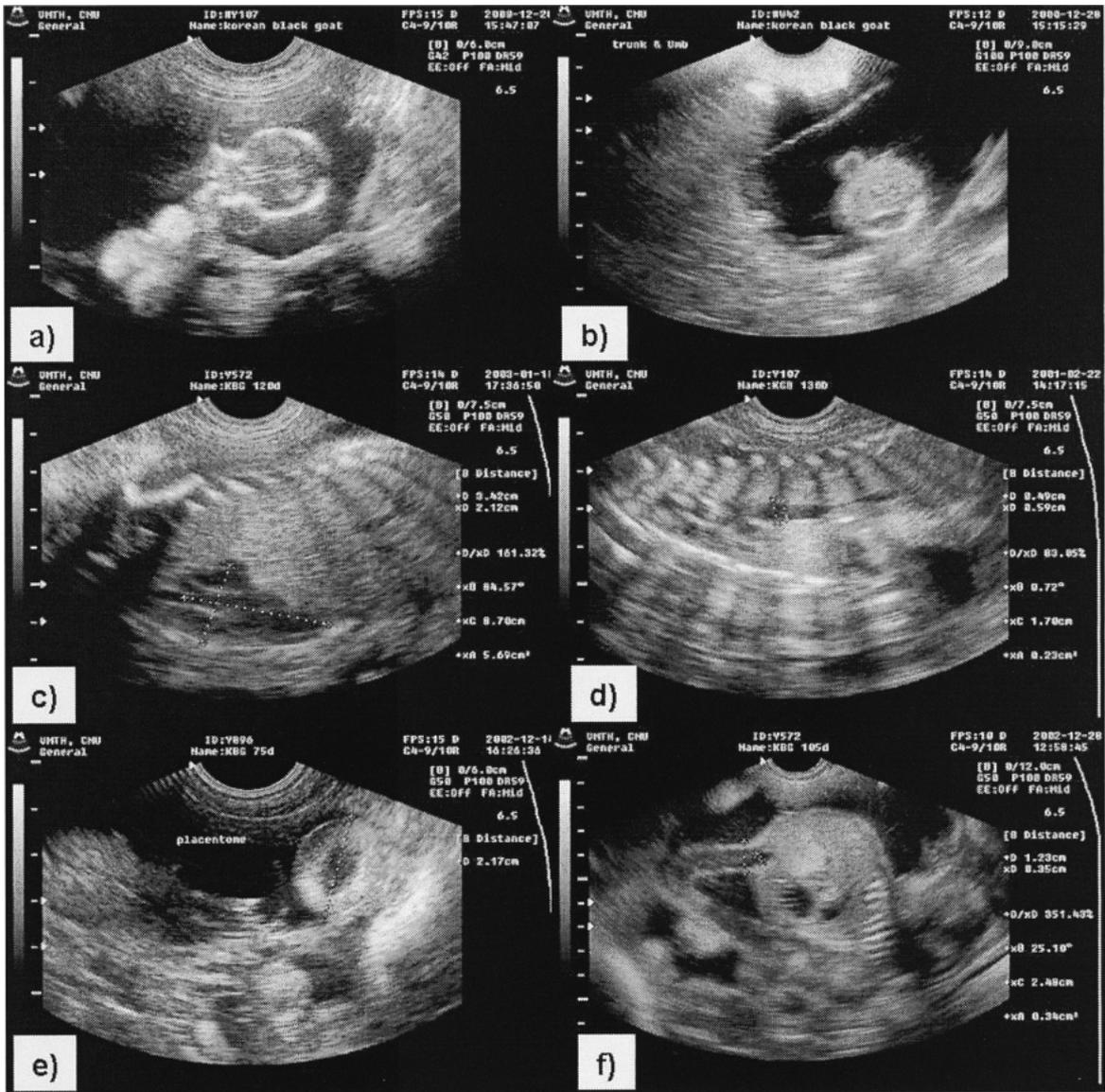


Fig. 1. Ultrasonographic image of fetal organs in Korean black goat. a)Head and Orbit, b) Trunk, c)Long and short axis of heart, d)Aorta, e)Placentome and f)Umbilical cord and vein.

Table 1. Measurements of head, orbit, trunk, placentome, heart, aorta, umbilical cord and vein by ultrasound at the different gestational age in Korean black goat fetus

Measurements (cm)	Gestational age (day; mean ± SD)					
	60*	75	90	105	120	135
Head	1.50 ± 0.39	2.74 ± 0.64	3.20 ± 0.70	3.59 ± 0.29	3.70 ± 0.28	4.19 ± 0.43
Orbit	0.95 ± 0.22	1.17 ± 0.19	1.37 ± 0.18	1.45 ± 0.14	1.74 ± 0.16	1.94 ± 0.13
Trunk	2.21 ± 0.38	3.68 ± 0.57	4.93 ± 0.61	5.68 ± 0.63	6.13 ± 0.58	6.91 ± 0.58
Long axis of heart	1.04 ± 0.25	1.38 ± 0.19	2.24 ± 0.28	2.56 ± 0.51	2.93 ± 0.33	4.00 ± 0.55
Short axis of heart	0.74 ± 0.16	1.05 ± 0.14	1.45 ± 0.23	1.86 ± 0.40	2.22 ± 0.43	2.58 ± 0.43
Aorta	0.22 ± 0.01	0.29 ± 0.05	0.37 ± 0.11	0.46 ± 0.07	0.53 ± 0.06	0.57 ± 0.07
Placentome	1.47 ± 0.24	1.89 ± 0.54	2.25 ± 0.29	2.25 ± 0.44	2.50 ± 0.41	2.58 ± 0.33
Umbilical cord	0.34 ± 0.06	0.89 ± 0.10	1.19 ± 0.26	1.21 ± 0.08	1.23 ± 0.09	1.29 ± 0.14
Umbilical vein	0.34 ± 0.05	0.39 ± 0.06	0.43 ± 0.04	0.45 ± 0.05	0.46 ± 0.04	0.48 ± 0.06

* Only 5 goats were measured because of difficulty in measuring the fetal organs. Aorta, placentome and umbilical cord was measured in only 3 goats.

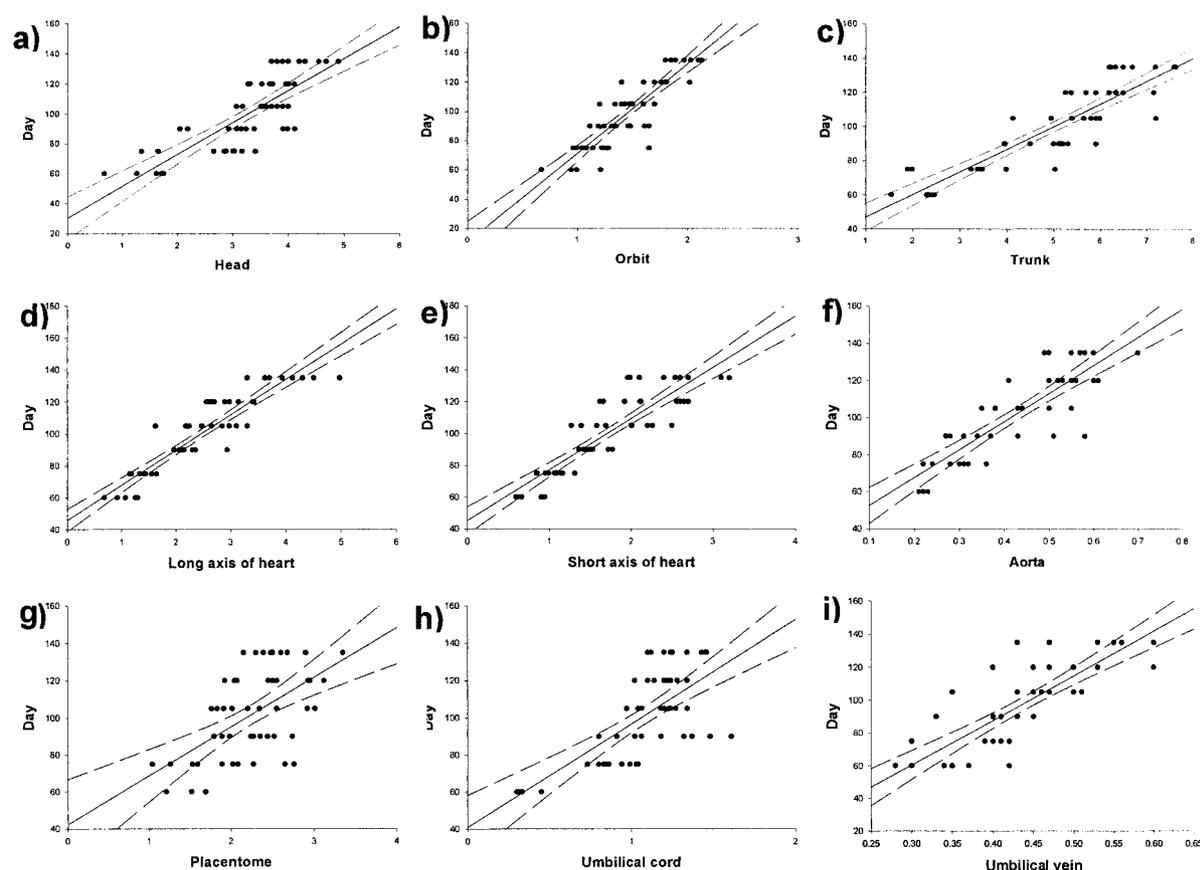


Fig. 2. Diameters (cm) of fetal organs at different gestational age (60–130days) in Korean black goats. a) Head, b) Orbit, c) Trunk, d) Long axis of heart, e) Short axis of heart, f) Aorta, g) Placentome, h) Umbilical cord and i) Umbilical vein.

Table 2. Regression equations of gestational age prediction from fetal ultrasonographic measurements in Korean black goats

Measurements	Equation	Coefficient value (r)
Head	$y = 21.3110x + 30.3119$	0.8089 ($p < 0.05$)
Orbit	$y = 60.9832x + 10.4719$	0.8737 ($p < 0.05$)
Trunk	$y = 13.2648x + 33.7059$	0.8876 ($p < 0.001$)
Long axis of heart	$y = 22.0779x + 45.8732$	0.9168 ($p < 0.001$)
Short axis of heart	$y = 32.0683x + 45.2564$	0.8819 ($p < 0.001$)
Aorta	$y = 151.1366x + 37.4774$	0.8507 ($p < 0.05$)
Placentome	$y = 26.5182x + 42.2374$	0.5740 ($p < 0.001$)
Umbilical cord	$y = 55.8769x + 40.9243$	0.7074 ($p < 0.001$)
Umbilical vein	$y = 271.2958 - 20.8824$	0.7892 ($p < 0.001$)

x; Diameter(cm) of parameter, y; gestational age (day).

was proved useful method for the estimation of the duration of pregnancy in Korean black goats. Especially, measurements of trunk, long and short axis of heart were appropriate parameters for estimating a gestational age. Additionally, measurements of head, orbit and aorta were effective on estimating a gestational age by its high correlation coefficients.

The head width, or biparietal diameter (BPD), was widely measured in the human and was mainly measured in the ani-

mal. In small ruminants during pregnancy, ultrasound-derived BPD data have been reported for various breeds of goats [8–10, 17], sheep [1, 5, 10] and red deer [2, 23]. Hailbel [8] reported that BPD was significantly increased with gestational age in dairy goats ($r^2=0.9811$). Reichle and Hailbel [17] also reported that BPD was highly correlated with gestational age when diameter of the head was measured at 2 to 3 days intervals from 36 days to 102 days in Pygmy goat ($r^2=0.9727$). In present study, although the coefficient of determination was relatively lower than previous studies, the diameter of fetal head were significantly increased with the fetal age and have high correlation ($r=0.8089$) with gestational age. It was thought that interval of examination duration in this study was longer than that of previous other studies

In the human, to evaluate the orbit or lens early in the pregnancy, it was possible to estimate not only gestational age but also fetal eye abnormalities were associated with various genetic diseases or malformations, such as Down syndrome and corpus callosum agenesis [3, 4]. However, it has not been reported for the fetal orbit in goats. The diameter of fetal orbit was measured through 60 days to 135 days of gestation with fetal head and the significant results were obtained from this trials ($r=0.8737$). It was thought that the

diameter of fetal orbit was useful parameter for the estimation of fetal parameter.

Measurement of fetal trunk diameter by ultrasonography was used generally for assessment of gestational ages in human and animals. However, in small ruminants, it was reported only in ewe [1] and red deer [2, 23]. Aiumlamai *et al.* [1] reported that coefficient value of fetal trunk diameter against gestational age in ewes was significant ($r=0.80$). White *et al.* [22] reported that mean fetal trunk diameter was also highly correlated with gestational age in cattle ($r=0.95$). In this study, these high correlation of fetal trunk and gestational age was also demonstrated in Korean black goats ($r=0.8876$). And, measurement of fetal trunk by ultrasonography had an advantage that it could be measured more easily than other parameters.

Measurement of cardiac size was used to estimate for heart state, cardiomegaly, myocardial hypertrophy and hypoxemic myocardial damage, of fetus in the human [15]. In this study, diameter of long and short axis of heart and aorta were evaluated, and both long and short axis were highly correlated with gestational age ($r=0.9168$, $r=0.8819$). However, diameter of long axis of heart was higher correlated with gestational age than short axis because diameter of short axis was changed with large variance in systolic-diastolic duration.

The diameter of placentome was also evaluated for estimating the gestational age, however it had the lowest lower correlation coefficient with gestational age than the other measurements ($r=0.5740$). For this lower correlation coefficient, many of placentome were usually appeared same image in the ultrasonography and size of each placentome was different with variable range regardless of gestational age. Especially, difference of placentome size between nearer portions with umbilical attachment in the uterus and uterine horn tip made a placentome size to poor parameter for estimating gestational age [10].

In human fetus, umbilical cord diameter ($r=0.78$), crown-rump length ($r=0.75$) and biparietal diameter ($r=0.81$) were significantly correlated with gestational age [6]. Similar with these human results, umbilical cord ($r=0.7074$) and vein ($r=0.7892$) diameter were also significantly correlated with gestational age in Korean black goat.

In summary, fetometry by ultrasonography was demonstrated to useful method for estimating the gestational age in Korean black goats. Especially, trunk, long axis of heart and short axis of heart are useful parameters its higher correlation coefficient with gestational age than other parameters. It is suggested that these are useful parameters for estimation of gestational age for reproductive management in Korean black goats.

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