FULL PAPER *Theriogenology*

Establishment of the Prediction Table of Parturition Day with Ultrasonography in Small Pet Dogs

Chang-ho SON[1)], Kyung-a JEONG[1)], Jeong-hun KIM[1)], In-chul PARK[1)], Sung-ho KIM[1)] and Cha-soo LEE[2)]

[1)]College of Veterinary Medicine, Chonnam National University, Kwangju 500–757 and [2)]College of Veterinary Medicine, Kyungpook National University, Taegu 702–701, Republic of Korea

(Received 1 March 2001/Accepted 13 March 2001)

ABSTRACT. To establish a prediction table of parturition day the real-time B-mode ultrasonographic examinations were performed in the 8 pregnant Malteses and 10 Yorkshire terriers (total pups, 25 and 38 pups, respectively) from 18 days of gestation until the parturition. Ovulation was designated the first day of gestation (day 0). Extra fetal and fetal structures were measured from all conceptues. The parameters that exhibited the best correlation to parturition were used to compile a prediction table of parturition day. To testify the precision of the prediction table of parturition day, the 15 pregnant Malteses (48 pups) and 13 pregnant Yorkshire terriers (42 pups) with unknown mating time were examined using ultrasonography. Inner chorionic cavity diameter on days 18 to 37 and fetal head diameter on day 38 to parturition that showed the best correlation to gestational age were the most pertinent to the estimation of gestational age and the prediction of parturition day. The two parameters were used to compile a prediction table of parturition with averaged regression equations. In verificational examinations, with the exception of 1 Yorkshire terrier (3.6%) having 1 fetus, 18 of 28 bitches (64.3%) delivered exactly on the date predicted and 9 of 28 bitches (32.1%) delivered within 1 day of the date predicted. Therefore, the prediction table of parturition day seems to be a useful tool of the prediction of parturition day in practice.

KEY WORDS: canine, gestational age, prediction table of parturition day, ultrasonography.

J. Vet. Med. Sci. 63(7): 715–721, 2001

The ability to determine gestational age and predict of parturition day would be an immense value in maintaining of normal pregnancy and in the assessment of fetal viability in case of threatened abortion or prolonged gestation [3, 11, 13]. Ultrasonography is a useful imaging modality for the estimation of gestational age and the prediction of parturition day as well as the complete reproductive assessment in several species [1, 5, 6, 9, 12]. Still more, a large number of congenital defects occur in the bitch, so their recognition is important to prevent potential dystocia [3]. In veterinary medicine, the estimation of gestational age based on anatomic appearance and the prediction of parturition day by ultrasonographic examination are partially characterized. England *et al.* [4] made assessments of the diameter of pregnancy structures in pregnant bitches. And Yeager *et al.* [15] made similar estimates of fetal size during pregnancy and found that the best correlation was between fetal head diameter and gestational age. Recently, Kim *et al.* [9] compiled the prediction table of parturition day in Korea Jin-do bitches. In the small pet dogs, no report has been published on the prediction table of parturition day.

The present study was designed to establish an accurate prediction table of parturition day based on measurements of gestational structures using ultrasonography in Maltese and Yorkshire terrier and to testify the precision of the prediction table of parturition day using additional pregnant bitches with unknown mating time.

MATERIALS AND METHODS

Tabulation of the predicted parturition day (basic experiments): The 8 pregnant Malteses and 10 pregnant Yorkshire terriers (total pups, 25 and 38 pups, respectively) were examined. The bitches weighed 3.12 to 3.5 and 1.7 to 3.6 kg at estrus, respectively. They were mated at estrus according to results of vaginal cytological evaluation.

Plasma progesterone concentrations were determined in duplicate with a commercial progesterone kit (Progesterone Coat-A-count, Diagnostic Products Corporation, Los angeles, CA) by Gamma counter (EG & G Wallace, Finland), as described by Kang *et al.* [7]. The intra- and inter-assay coefficients of variation were 5.1% and 8.2%, respectively. Ovulation was estimated to occur when plasma progesterone concentration first increased above 4.0 *n*g/m*l*, as described by Kim *et al.* [8] and Wallace *et al.* [16]. And ovulation was designated the first day of gestation (day 0).

Serial ultrasonographic examinations were performed daily from 15 days of gestation until parturition. All bitches were examined using real-time B-mode ultrasonography in dorsal recumbency. Ultrasonographic examinations were performed using Sonoace 4800 HD (Medison Co., Korea) with a 3.5, 6.5 or 7.5 MHz transducer. Measurements were undertaken from all conceptuses. All diameters were described in millimeters.

Extra fetal structures were examined according to following methods: Outer uterine diameter was measured outer diameters of the uterine horn at implantation sites. It was calculated to be the mean value of the dorsal-to-ventral and medial-to-lateral diameters. Inner diameter of chorionic cavity was measured at the location of the zonary placenta once it was detectable. It was calculated to be the mean value of the dorsal-to-ventral and medial-to-lateral diameters. Length of chorionic cavity or zonary placenta was measured until zonary placenta was recognizable, after that

time, length of zonary placenta was measured.

Fetal structures were examined according to following methods: Fetal head diameter was measured as the largest cross-sectional diameter of the head or the biparietal diameter when this structure was well identified in longitudinal section. The image quality was initially assessed by symmetry of the section and later in pregnancy by the central location of an echogenic line produced by the falx cerebri in the fetal head. Fetal body diameter was measured as the largest cross-sectional diameter of the body of the fetus at the level of the liver and stomach in the thoracic region when these could be identified. Fetal crown-rump length was measured the distance from the skull to the caudal edge to the perineum.

Statistical analysis: All of the measurements were explored with regression analysis by Pearson's correlation procedure of SAS. An averaged regression equations derived from parameters chosen that exhibited the best correlation to parturition were used to compile a prediction table of parturition. A Pearson's p value <0.05 was considered significant.

Verificational experiment: To testify to precision of the table of the prediction of parturition day obtained in basic experiments, the 15 pregnant Malteses (48 pups) and 13 pregnant Yorkshire terriers (42 pups) with unknown mating time were examined using ultrasonography by the method previously described. Inner chorionic cavity diameter was measured before fetal skeleton was visualized and fetal head diameter was measured after fetal skeleton was visualized. These results were applied to the prediction table of parturition day and compared with actual parturition day.

RESULTS

Tabulation of the predicted parturition day (basic experiment): The gestation lengths timed from the day of ovulation were 63.2 ± 0.8 days (mean ± S.D., range, 62–64 days) and 63.4 ± 0.5 days (63–64 days) in Maltese and Yorkshire terrier, respectively.

To examine of the development of extra-fetal structures relative to gestational age, the growth of extra-fetal structures such as outer uterine diameter, inner chorionic cavity diameter and length of chorionic cavity or zonary placenta diameter were measured daily after day 18 and the results were presented in Fig. 1 and Fig. 2. The correlations between the each parameters and gestational age during gestation were expressed by the coefficients of correlation (Table 1).

As shown in Table 1, the regressions of outer uterine diameter and inner chorionic cavity diameter were significantly and linearly relative to gestational age, whereas the regression of zonary placenta length was not significantly relative to gestational age compared with those of the other extra-fetal structures. Of the extra-fetal structures, inner chorionic cavity diameter showed the best correlation to gestational age before day 37 of gestation.

To examine of the development of fetal structures relative to gestational age, we measured the growth of fetal structures such as fetal head diameter, fetal body diameter and fetal crown-rump length daily after these structures could be identified, and the results were in Fig. 1 and Fig. 2. The correlations between the each parameters and gestational age were expressed by the coefficients of correlation (Table 2).

As shown in Table 2, the regressions of fetal head diameter and fetal body diameter each were significantly and linearly relative to gestational age, but the regression of fetal crown-rump length was not significantly relative to gestational age compared with those of the other fetal structures. Of the fetal structures, fetal head diameter showed the best correlation to gestational age on days 38 to parturition.

Inner chorionic cavity diameter on day 18 to 37 and fetal head diameter on day 38 to parturition which were generated the best correlation to gestational age were used to compile a prediction table of parturition with averaged regression equations (Tables 3, 4).

Verificational experiment: The 15 pregnant Malteses (48 pups) and 13 pregnant Yorkshire terriers (42 pups) with unknown mating time were examined to assess an accuracy of the table of prediction of parturition day obtained in basic experiments. And these results were applied to the prediction table of parturition day and compared with actual parturition day. The results were presented in Table 5.

Based on inner chorionic cavity diameter, 6 of 8 Malteses (75.0%) and 5 of 6 Yorkshire terriers (83.3%) delivered exactly on the date predicted and the others of two breeds of dog delivered within 1 day of the date predicted. Based on fetal head diameter, with the exception of 1 Yorkshire terrier (Bitch No. 28) having only one fetus, 4 of 7 Malteses (57.1%) and 3 of 6 Yorkshire terriers (50.0%) delivered exactly on the date predicted and the remainder of two breeds of dog delivered within 1 day of the date predicted. In 1 Yorkshire terrier having only one fetus, the actual parturition day was consistent with the predicted parturition day made on basis of measurement of head diameter on 23 days prepartum and it was two days later than the predicted parturition day made on basis of measurement of head diameter on 7 days prepartum.

With the exception of 1 Yorkshire terrier (3.6%) having 1 fetus, that is, 18 of 28 bitches (64.3%) delivered exactly on the date predicted and 9 of 28 bitches (32.1%) delivered within 1 day of the date predicted.

DISCUSSION

The results of this study revealed that the regressions of outer uterine diameter and inner chorionic cavity diameter were significantly and linearly related to gestational age, whereas the regression of length of zonary placenta was not significantly related to gestational age compared with those of other extra-fetal structures. These results contradict the work of Yeager *et al.* [15], who suggested there was significant linear correlation between gestational age and all extra-fetal structures. Of the above structures, inner chorionic cavity diameter was easier to measure than the other

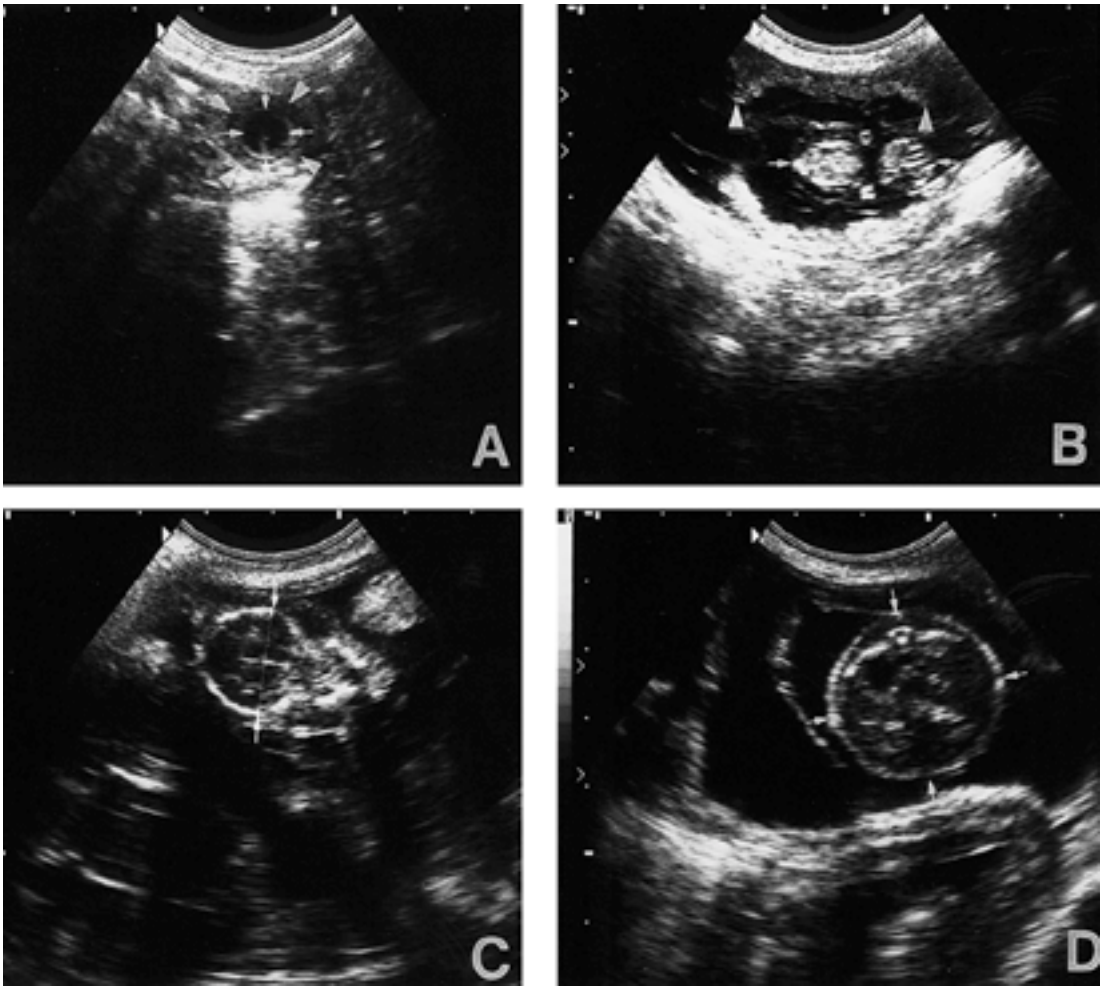

Fig. 1. Serial ultrasonograms of pregnant bitches (in Maltese and Yorkshire terrier). Day 0 is the first gestational day (ovulation day). A) On day 25, gestational sac with amniotic fluid and embryo mass. Outer uterine diameter (arrow heads) and inner chorionic cavity diameter (white arrows) are seen in transverse plane. B) On day 35, gestational sac with zonary placenta, allantoamnion and fetus. Length of zonary placenta is marked by arrow heads, and fetal crown-rump length is marked by white arrows. C) On day 45, fetal head diameter (white arrows) in transverse plane. The falx cerebri is clearly recognizable as a hyperechoic line in the center of the fetal skull. D) On day 48, hyperechoic vertebra, anechoic stomach, hypoechoic liver and anechoic blood vessels in fetus. Fetal body diameter (white arrows) is seen in transverse plane.

extra-fetal structures because it was seen distinctly as anechoic, round structures with an overt bounds that produced characteristic bright specular echoes and it showed the best correlation to gestational age before day 37. After day 38, the uterus was converted, irregular shape in the cross-section, and grew slowly. The relatively volume of fetal fluid decreased compared with the size of fetus, and the fetus was closely associated with the wall of chorionic cavity. For this reason, above structures were difficult to measure after day 38. Therefore, inner chorionic cavity diameter on day 18 to 37 was the most pertinent to the estimation of gestational age and the prediction of parturition, as in previous reports [12, 15].

Of fetal structures, fetal head diameter and fetal body diameter increased at an almost fixed rate and the regression was significantly and linearly related to gestational age on day 38 to parturition, as in the previous studies [4, 10, 15]. Fetal crown-rump length increased at linear rate on days 35 to 49, but the regression of fetal crown-rump length was not significantly relative to gestational age compared with those of other fetal structures. After day 28 when fetal head could be identified, fetal head diameter was possible to measure, but the reliable measurement of fetal head diameter on days 28 to 37 was disturbed because ossification of the skeleton was defective and allantoic membrane was closely associated with fetus. This finding was similar to the report of Beck *et al.* [2]. Also, it was also difficult to measure fetal body diameter accurately on days 28 to 37 due to a close-by

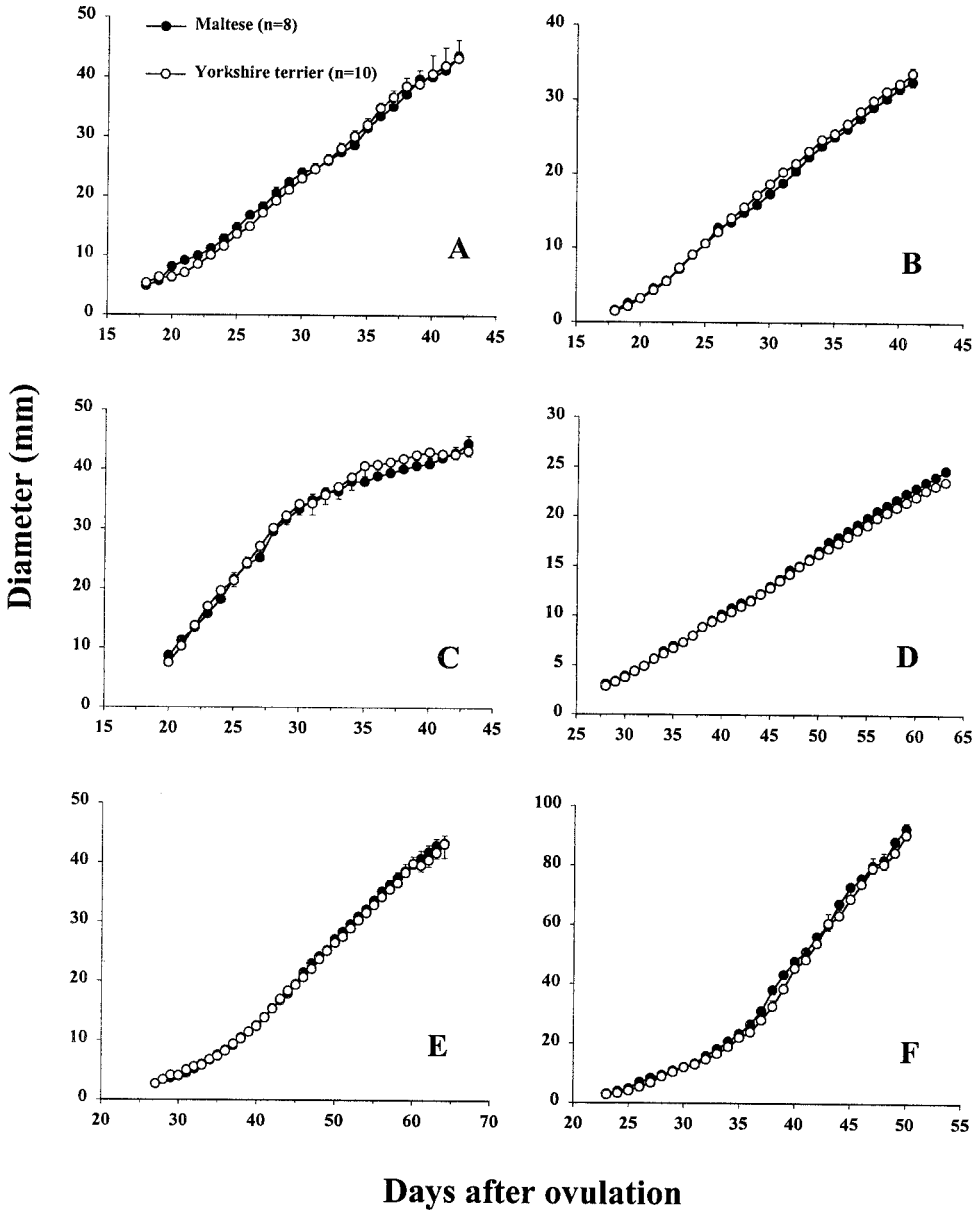

Fig. 2. Measurement of the mean (± S.E.M.) A) outer uterine diameter, B) inner chorionic cavity diameter, C) length of zonary placenta, D) fetal head diameter, E) fetal body diameter, and F) fetal crown-rump length. Day 0 is the first gestational day (ovulation day).

allantoic membrane with fetus and an appropriate scan plan was difficult to acquire because fetal body was just beginning to develop as fetus head was. After day 38, fetal head diameter was easier to measure than the other fetal structures because an accurate scan plane of this structure was easy to obtain as ossification of the skeleton proceeded, whereas an accurate scan plan of fetal body diameter was difficult to obtain as fetus grew because the fetus was close to the wall of chorionic cavity, and so fetal body was difficult to differentiate from the wall of chorionic cavity. And it was consistent with the report of Son *et al.* [12]. For the reason previously mentioned, fetal head diameter on day 38 to parturition that showed the best correlation to gestational age was the most pertinent to the estimation of gestational age and the prediction of parturition, as in the previous studies [12, 15].

The coefficients of correlation of inner chorionic cavity diameter before day 37 and fetal head diameter after day 38 were scrutinized at intervals of 6 days in two breeds. Inner chorionic cavity diameter from days 20 to 25 and fetal head

Table 1. The averaged regression equations and the coefficients of correlation for extra-fetal structures relative to gestational age ($p<0.05$)

Pregnancy features	Breed	OUD[c)]		ICCD[d)]		PL[e)]	
		Equation	r^2	Equation	r^2	Equation	r^2
Days	M[a)]	Y=16.08+0.59X	0.98	Y=18.58+0.71X	0.99	Y=15.24+0.48X	0.84
20 to 37	YT[b)]	Y=18.03+0.52X	0.97	Y=18.92+0.65X	0.99	Y=19.06+0.39X	0.89
Day 38	M	Y=21.23+0.48X	0.74	Y=21.50+0.62X	0.85	Y=23.84+0.40X	0.31
to parturition	YT	Y=26.39+0.34X	0.57	Y=16.61+0.74X	0.71	Y=23.78+0.40X	0.36
Day 20	M	Y=15.77+0.61X	0.98	Y=18.72+0.71X	0.99	Y=11.74+0.63X	0.82
to parturition	YT	Y=17.78+0.54X	0.97	Y=19.07+0.64X	0.99	Y=16.36+0.51X	0.87

a) Maltese. b) Yorkshire terrier. c) Outer uterine diameter. d) Inner chorionic cavity diameter. e) Placental length. X: Diameter of structure. Y: Gestational age.

Table 2. The averaged regression equations and the coefficients of correlation for fetal structures relative to gestational age ($p<0.05$)

Pregnancy features	Breed	HD[c)]		BD[d)]		CRL[e)]	
		Equation	r^2	Equation	r^2	Equation	r^2
Days	M[a)]	Y=24.03+1.59X	0.93	Y=25.75+1.21X	0.92	Y=23.70+0.47X	0.91
20 to 37	YT[b)]	Y=24.50+1.52X	0.93	Y=26.19+1.12X	0.90	Y=24.27+0.48X	0.92
Day 38	M	Y=24.70+1.54X	0.99	Y=30.64+0.73X	0.98	Y=30.19+0.21X	0.95
to parturition	YT	Y=23.89+1.63X	0.99	Y=30.52+0.75X	0.97	Y=32.23+0.18X	0.93
Day 20	M	Y=24.36+1.55X	0.99	Y=29.35+0.77X	0.98	Y=26.41+0.28X	0.93
to parturition	YT	Y=23.87+1.63X	0.99	Y=29.08+0.80X	0.98	Y=27.41+0.27X	0.91

a) Maltese. b) Yorkshire terrier. c) Head diameter. d) Body diameter. Crown-rump length. X: Diameter of structure. Y: Gestational age.

Table 3. Calculation of predicted parturition day by using the measurement of inner chorionic cavity diameter on day 20 to 37 and fetal head diameter on day 38 to parturition in Maltese and Yorkshire terrier, respectively

Pregnancy structures	Maltese	Yorkshire terrier
Inner chorionic cavity diameter (ICCD)	Y=63.2–(18.58+0.71X) $p<0.05$ $r^2 = 0.99$ X = ICCD Y = days prepartum	Y=63.4–(18.92+0.65X) $p<0.05$ $r^2 = 0.99$ X = ICCD Y = days prepartum
Head diameter (HD)	Y=63.2–(24.7+1.54X) $p<0.05$ $r^2 = 0.99$ X = HD Y = days prepartum	Y=63.4–(23.89+1.63X) $p<0.05$ $r^2 = 0.99$ X = HD Y = days prepartum

diameter from days 38 to 43 generated the best correlation to gestational age and these data suggested that an estimation of gestational age and a prediction of parturition are more accurate in this period. It was similar to the previous findings of Yeager and Concannon [14], who suggested that the estimation of the length of gestation is probably more accurate during the second trimester, because at this stage, the breed of dog and the number of fetuses in the litter have less influence on pregnancy size than in the third trimester.

In verificational examinations, with the exception of 1 Yorkshire terrier (3.6%) having 1 fetus, 18 of 28 bitches (64.3%) delivered exactly on the date predicted and 9 of 28 bitches (32.1%) delivered within 1 day of the date predicted. These results were similar to those in the studies by Kim *et al.* [9] and Beck *et al.* [2]. By way of exception, in 1 Yorkshire terrier having only 1 fetus, the actual parturition day was consistent with the predicted parturition day made on basis of measurement of head diameter on 23 days prepartum and it was two days later than the predicted parturition day made on basis of measurement of head diameter on 7 days prepartum. These confirm the above-cited report by Yeager and Concannon [14].

The above facts verify that inner chorionic cavity diameter before 37 day and fetal head diameter from 38 day to parturition are valuable parameters for the prediction of parturition day in the bitch. And the prediction table of par-

Table 4. The prediction table of parturition day using the regression equations for inner chorionic cavity diameter from 45 to 26 days prepartum and fetal head diameter from 25 days prepartum to parturition

ICCD[a](mm)	Days prepartum		HD[b](mm)	Days prepartum	
	Maltese	Yorkshire terrier		Maltese	Yorkshire terrier
2	43	43	8.5	25	26
3	42	43	9	25	25
4	42	42	9.5	24	24
5	41	41	10	23	23
6	40	41	10.5	22	22
7	40	40	11	22	22
8	39	39	11.5	21	21
9	38	39	12	20	20
10	38	38	12.5	19	19
11	37	37	13	18	18
12	36	37	13.5	18	18
13	35	36	14	17	17
14	35	35	14.5	16	16
15	34	35	15	15	15
16	33	34	15.5	15	14
17	33	33	16	14	13
18	32	33	16.5	13	13
19	31	32	17	12	12
20	30	31	17.5	12	11
21	30	31	18	11	10
22	29	30	18.5	10	9
23	28	30	19	9	9
24	28	29	19.5	8	8
25	27	28	20	8	7
26	26	28	20.5	7	6
27	–	27	21	6	5
28	–	26	21.5	5	4
29	–	26	22	5	4
			22.5	4	3
			23	3	2
			23.5	2	1
			24	2	0
			24.5	1	–
			25	0	–

a) Inner chorionic cavity diameter. b) Head diameter.

turition day seems to be a useful tool of the prediction of parturition day in veterinary practice.

ACKNOWLEDGEMENT. This study was financially supported by Chonnam National University in the program, 1999.

REFERENCES

1. Aiumlamai, S., Fredriksson, G. and Nilsfort, L. 1992. Real-time ultrasonography for determining the gestational age of ewes. *Vet. Rec.* **131**: 560–562.
2. Beck, K.A., Baldwin, C.J. and Bosu, W.T.K. 1990. Ultrasound prediction of parturition in queens. *Vet. Radiol.* **31**: 32–35.
3. England, G.C.W. 1998. Ultrasonographic assessment of abnormal pregnancy. *Ultrasonography* **28**: 849–867.
4. England, G.C.W., Allen, E.W. and Porter D.J. 1990. Studies on canine pregnancy using B-mode ultrasound: Development of the conceptus and determination of gestational age. *J. Small. Anim. Pract.* **31**: 324–329.
5. England, G.C.W. and Yeager, A.E. 1993. Ultrasonographic appearance of the ovary and uterus of the bitch during oestrus, ovulation and early pregnancy. *J. Reprod. Fertil. (Suppl.)* **47**: 107–117
6. Kähn, W., Fraunholz, J., Kaspar, B. and Pyczak T. 1990. Sonographic diagnosis of early pregnancy in horses, cattle, sheep, goats, swine, dogs and cats. Standard values and limitations. *Berl. Munch. Tierärztl. Wöchenschr.* **103**: 206–211.
7. Kang, B.K., Choi, H.S., Choi, S.G. and Son, C.H. 1994. Progesterone assays as an aid for improving reproductive efficiency in dairy cattle. I. Use of milk progesterone profiles in the confirmation of estrus detection and early pregnancy diagnosis. *Korean J. Vet. Res.* **34**: 173–180.
8. Kim, J.H., Jeong, K.A., Kang, H.G., Oh, K.S., Park, I.C., Park, S.G., Han, H.J. and Son, C.H. 2000. Relationship between vaginal cytology and reproductive hormone during the estrous cycle in Korea Jin-do bitches. *Korean J. Vet. Clin. Med.* **17**: 225–233.
9. Kim, S.R., Kang, H.G., Oh, K.S., Park, I.C., Park, S.G. and Son, C.H. 2000. Establishment of prediction table of parturition day by ultrasonography in Korean Jindo bitches. *Korean J. Vet. Res.* **40**: 373–381.
10. Moriyashi, M., Waki, Y., Nakao, T. and Kacoata, K. 1996.

Table 5. Comparison of the expected parturition day with actual parturition day

Bitch No.	Breed	ICCD[c] (mm)	HD[d] (mm)	Predicted days prepartum	Actual days prepartum	Predicted minus actual
1	M[a]	10.01		38	37	+1
2	M	9.03		38	38	0
3	M	20.05		30	30	0
4	M	24.70		27	27	0
5	M	22.85		28	29	-1
6	M	4.57		41	41	0
7	M	13.49		35	35	0
8	M	25.84		26	26	0
9	M		14.87	16	15	+1
10	M		10.10	23	23	0
11	M		13.00	18	18	0
12	M		10.75	22	22	0
13	M		23.20	3	4	-1
14	M		18.20	10	10	0
15	M		17.00	12	11	+1
16	YT[b]	2.57		43	43	0
17	YT	11.79		37	37	0
18	YT	24.53		29	29	0
19	YT	14.57		35	35	0
20	YT	27.45		27	28	-1
21	YT	5.81		41	41	0
22	YT		20.10	7	8	-1
23	YT		9.80	24	24	0
24	YT		21.70	4	4	0
25	YT		10.15	23	23	0
26	YT		12.70	19	18	+1
27	YT		14.34	16	15	+1
28	YT		10.31	23	23	0
			21.30	5	7	–2

a) Maltese. b) Yorkshire terrier. c) Inner chorionic cavity diameter. d) Head diameter.

Observation of the growth process of a beagle embryo and fetus by ultrasonography. *J. Vet. Med. Sci.* **58**: 443–445.

11. Nautrup, P.C., Tobias, R. and Cartee, R.E. 2000. Pregnancy and parturition, mammary gland. pp. 290–329. In: An Atlas and Textbook of Diagnostic Ultrasonography of the Dog and Cat, Manson Publishing, London.
12. Son, C.H., Shin, C.R., Kang, B.K. and Choi, H.S. 1996. Ultrasonographic appearance of the gestational structures throughout accurately timed pregnancy in Korea Jin-do dogs. II. Estimation of gestational age by measurement of the fetal and extra-fetal structures. *Korean J. Vet. Res.* **36**: 247–254.
13. Yeager, A.E. and Concannon, P.W. 1995. Ultrasonography of the reproductive tract of the female dog and cat. pp. 1040–1052. In: Kirk's Current Ceterinary Therapy, XII. Small Animal Practice (Bonagura J.D. ed.), WB Saunders, Philadelphia.
14. Yeager, A.E. and Concannon, P.W. 1996. Uterus. pp. 265–292. In: Small Animal Ultrasound, Lippincott-Raven, Philadelphia.
15. Yeager, A.E., Mohammed, H.O., Meyers-Wallen, V., Vannerson, L. and Concannon, P.W. 1992. Ultrasonographic appearance of the uterus, placenta, fetus, and fetal membranes throughout accurately timed pregnancy in Beagles. *Am. J. Vet. Res.* **53**: 342–351.
16. Wallace, S.S., Mahaffey, M.B., Miller, D.M., Thompson, F.N. and Chakraborty, P.K. 1992. Ultrasonographic appearance of the ovaries of dogs during the follicular and luteal phases of the estrus cycle. *Am. J. Vet. Res.* **53**: 209–215.