Studies on pregnancy diagnosis in domestic animals by an ultrasonic Doppler method

II. An evaluation for predicting the litter size in utero in the pig^{*1}

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SUMMARY. Litter size in utero was estimated with an ultrasonic Doppler apparatus ("Heart-tone" USD-I, Aloka Co. Ltd., Tokyo) in 16 pregnant sows including three different breeds. In 15 out of 16 sows, experimental period was from 80 to 114 days of pregnancy, while in the remaining one sow experiments were undertaken during 58 to 107 days of pregnancy. Each experiment was carried out non-surgically at a sleeping position with neither restraint nor anaesthesia.

The results obtained were as follows.

- 1) In 5 out of 20 experiments, the estimated litter size was in accord with the actual number farrowed at parturition. In the remaining 15 experiments, however, errors of the estimation ranged from -5 to +3 piglets.
- 2) Cases of which the errors were less than ± 1 , ± 2 and ± 3 piglets, were 9 out of 20 (45%), 14 out of 20 (70%) and 17 out of 20 (85%) experiments, respectively.
- 3) The accuracy of estimation of the litter size tended to be higher after 91 days of pregnancy than before 90 days ($P < 0.10$), and it tended to be low when the actual number of fetuses was more than 10, as compared with less than 9 piglets.
- 4) No harmful effects were observed in both fetuses and dams by the ultrasonic treatment used in this study.

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Introduction

Sows have a big litter size, and delay of farrowing and fetal deaths often occur by wasting physical condition of a dam. If the litter size was known before farrowing, it

could be possible to perform earlier and more suitable treatment for disorders of farrowing and it might be able to decrease the stillbirths. Furthermore, the personal labors requiring before and during farrowing will also be lessened by predicting the end of farrowing. Establishment of the estimating method of the litter size will make a deal of contributions to the pig farmers.

For the diagnosis of pregnancy in sows, several methods, including a vaginal biopsy test (WALKER¹⁾ and WILLIAMSON & HENNESSY²⁾, a hormonal treatment (DOICHEV³⁾, a X-ray method (WINTZER⁴⁾, a rectal examination (KEEL-DIFFEY⁵⁾, an urine test (CUPPS *et al.*⁶⁾, and an ultrasonic method (FRASER & ROBERTSON⁷⁾),

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and TOO *et al.*⁸⁾, have been reported. Estimation of the litter size in utero of sows has been conducted only by palpation and perception. Although the studies on estimation of the litter size in ewes and goats have been performed by an X-ray method (FORD *et al.*⁹⁾ and BARKER & COWLEY¹⁰⁾, there are many unsolved problems for the safety and the restraint of animals.

Several workers (HULET¹¹⁾, KEANE¹²⁾, WILSON & NEWTON¹³⁾, FRASER *et al.*¹⁴⁾ and LINDAHL¹⁵⁾ have described the possibility of an ultrasonic Doppler method for estimating multiple pregnancy in sheep. However, there is no available information for estimation of the litter size in sows by this means.

The purpose of the present study was to evaluate the ultrasonic Doppler method for the estimation of the litter size at the various stages of pregnant sows.

Materials and Methods

Equipment: The instrument used in this study was a proto-type fetal pulse detector, "Heart-tone" Model USD-I (Aloka Co. Ltd.) (TOO *et al.*⁸⁾, and KAWATA and FUKUI¹⁶⁾. "Heart-tone" consists of a speaker, two earphones and a probe. The probe, containing both a transmitter and a receiver, is light and compact (80 g weight and 9.8 cm length). A continuous ultrasound of 2.25 MHz in frequency and 30 mW/cm² in intensity was transmitted from the transmitter of the probe and the reflected signal was detected by the receiver. The reflected signals were audible by the speaker or earphone and were taperecorded. The system block diagram of the ultrasonic apparatus has already shown in the previous paper (TOO *et al.*⁸⁾).

Animals: Sixteen sows used in this study were 58 to 114 days of pregnancy after the last mating. Items in breed were Large White

(4 heads), Landrace (9 heads) and Hampshire (3 heads). Fifteen out of 16 sows have belonged to the Takikawa Animal Husbandry Experimental Station, Hokkaido. The 15 sows were examined only once during pregnancy from 80 to 114 days after the last mating, meanwhile the remaining one sow was examined five times at the pregnancy period of 58 to 107 days after the last mating.

Detection method of fetal circulation: Each experiment was carried out in the sow lying flat on the floor and keeping quiet with neither restraint nor anaesthesia. Each body side was examined for about fifteen minutes (total about 30 min. per sow). As a bland coupling medium, liquid paraffin was used to exclude air between the probe and the abdominal skin of dams. The probe was placed at the almost all areas of the abdominal skin, especially near the each nipple, between the nipples and in just front of the *Articulus genus*. Before or after detection of fetal heart pulse, maternal heart pulse was also recorded to compare with that of fetus. Doppler signals of a continuous and rhythmical character and of a faster rate than the maternal pulse rate are known to be from the fetal circulatory system¹⁷⁾.

Criterion for estimation of the litter size: When two or more Doppler signals from the fetal circulation (fetal heart) were detected at several locations, it was very important to distinguish whether these signals have been reflected from the same fetus or not. For example, when two fetal heart pulses were detected at two different locations and the Doppler signals transmitted had come across inside of the sow's body (i.e. uterus) according to the direction of the probe, it was estimated that the two heart pulses were reflected from one fetus. When the two Doppler signals did not come across inside of

Table 1-a. Summary of the results in the 15 sows

No. of experiment	Breeds* ¹	No. of deliveries* ²	Gestation days	Estimated litter size	Actual litter size
1	W	6	80	13	12* ³
2	L	5	80	11	9* ³ (4)* ⁴
3	L	2	85	14	12
4	L	2	90	8	8
5	L	2	90	10	7
6	L	2	91	12	10(2)* ⁴
7	W	5	93	12	16
8	H	2	97	10	12
9	L	4	100	13	14(1)* ⁴
10	L	6	102	10	10
11	W	2	103	8	9
12	H	3	103	11	11
13	H	2	104	9	9
14	L	5	111	10	15
15	W	5	114	10	8

*¹ W: Large White, L: Landrace, H: Hampshire.

*² The figures are included the present pregnancy.

*³ Two mummified fetuses were not included in the actual litter size.

*⁴ The figures in the parenthesis show still-born piglets which were included in the actual litter size.

the sow's body (i.e. uterus), it was estimated that the two heart pulses were produced from different fetuses. Thus, the most important point for differentiation of each fetus was the direction of the probe placed on the abdominal skin and the distance of each location detected the fetal Doppler signals. These criterions have depended upon that an ultrasonic sound runs straightly forward in the state of "no-air".

Results

Table 1-a shows the results of an experiment in 15 pregnant sows between 80 and 114 days and Table 1-b shows the results of five experiments in one pregnant sow between 58 and 107 days. As shown in Table 1-a, the estimated litter size was correct in 4 out of 15 sows. In Table 1-b, the correct estimation or the litter size was only in the experiment on 94 days of pregnancy, although the estimated litter size increased with progress of preg-

Table 1-b. Results of five experiments in the one sow*

No. of experiment	Gestation days	Estimated litter size	Actual litter size
1	58	9	13
2	64	10	13
3	85	10	13
4	94	13	13
5	107	14	13

* Breed: Landrace.

No. of delivery: 2 (included the present pregnancy).

nancy. In total, the litter size was correctly estimated in 5 out of 20 experiments (25%). Errors between the estimated and the actual litter size are shown in Table 2. Nine out of 20 (45%), 14 out of 20 (70%) and 17 out of 20 (85%) experiments were within the errors of ± 1 , ± 2 and ± 3 piglets, respectively. When the actual litter size was divided into two groups, less than 9 ($\geq$) and more than 10 ($\leq$) piglets, the estimated litter size of the former appeared to have been detected more

Table 2. Errors between the estimated and the actual litter size

Errors	No. of sows estimated litter size	The actual litter size	
		≤ 9	$10 \leq$
-5	1	0	1
-4	2	0	2
-3	2	0	2
-2	1	0	1
-1	2	1	1
0	9 5 14 17	2	3
+1	2	0	2
+2	4	2	2
+3	1	1	0
Total	20	6	14

Table 3. The relationships of the gestation days and the errors between the estimated and the actual litter size

Errors	Gestation days				Total
	≤ 80	81~90	91~100	101~114	
0	0	1	1	3	5
± 1	1	0	1	2	4
± 2	1	1	2	1	5
± 3	1	2	0	0	3
± 4	1	0	1	0	2
± 5	0	0	0	1	1
0- ± 2	2/4	2/4	2/4	6/7	14/20
(%)	(50.0%)	(50.0%)	(80.0%)	(85.5%)	(70.0%)
Total	4/8		10/12		
(%)	(50.0%)		(83.3%)*		

* $P < 0.10$.

than the actual litter size. In the latter, the accuracy of the estimated litter size tended to be lower than that of the litter size with less than 9 piglets.

Table 3 shows the relationships of the gestation days and the errors between the estimated and the actual litter sizes. The gestation days has no significant influence on the errors of estimation, though the accuracy of estimation tended to be higher after 91 days than before 90 days of pregnancy (83.3% v 50.5%; $P < 0.10$, $\chi^2 = 2.54$, d.f.1).

In the sows examined, seven still-births occurred in 3 sows (4.0%) and two mummifi-

cations also occurred in each of 2 sows. However, these figures were lower than that of common occurrence^{18,19}.

Discussion

The errors between the estimated and the actual litter sizes would have been produced by the occasional oversight of fetuses and the difficulty of making a clear differentiation of fetuses detected at different locations. A major cause of under the estimated litter size was the oversight of fetuses, and a major cause of over the estimated litter size would be that. When examinations were

performed in front of the *Articulus genus* and the dorsal side of the mammary gland, the probe had to be placed with the direction of downward. Thus, it might have occurred that the fetal circulation in the other side of the uterine horn was detected.

FRASER *et al.*¹⁴⁾ reported that an important problem in sheep seemed to be related to the difficulty of making accurate distinction among the heart rates of multiple fetuses in the uterine horn. In the present study, the distinction among the heart rates of Doppler signals recorded at different locations appeared to be possible. However, the difference of fetal heart rates was not regarded as a critical problem in this study.

There was no clear relationships among the errors of estimation, the difference in breeds and the number of deliveries in sows. It appeared in Hampshire sows that the errors between the estimated and the actual litter sizes were not very high. Sakuma *et al.*²⁰⁾ reported that the actual litter size tends to increase from the 3rd to 6th delivery. In this respect, sows would gain in weight and increase their volume with the number of delivery and growth. Thus, the accuracy of estimation of the litter size might be lower, when the number of delivery increases.

There are several reports on the safety of ultrasonic application (HOLMES & HOWRY²¹⁾, TALYER *et al.*²²⁾ and BISHOP²³⁾). BARTON²⁴⁾ described that injurious effects by ultrasonic treatment have been related to both intensity and exposure time employed. FRASER & ROBERTSON⁷⁾ reported that in ultrasonics used for tissue destruction, an intensity of 100 W/cm² has been employed. However, they also added that only 2.8 mW/cm² has been required for diagnostic ultrasonics. SHŌJI *et al.*²⁵⁾ reported that mouse on the 9th day of

gestation radiated with a frequency of 2.25 MHz and an intensity of 40 mW/cm² of ultrasound waves by a Doppler instrument for 5 hours produced some external abnormalities and increased fetal mortality. In the present study, the time of examination of each sow (about 30 min.) was longer than that of pregnancy diagnosis, so that the authors had worried about some harmful effects on fetuses to occur. However, in the present study, no abortion occurred and a total of 7 still-births in 3 sows, the rate (4.0%) of lower than that of common occurrence was produced^{18,19)}. It appears that no harmful effects will be produced by the ultrasonic sound used in the study.

It was concluded from the present study that the estimation of the litter size in the pig by means of an ultrasonic Doppler method could be possible, but the accuracy was somewhat low (25.0%). Further intensive studies would be needed for improvement of the accuracy before successful application in the field.

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超音波ドップラー法による家畜の妊娠診断

II. 豚の胎児数予測

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豚の妊娠診断については今日まで多くの方法が発表されているが、胎児数の予測は臨床上全く行われていないといってよい。豚は他の家畜に比べ胎児数が多く、分娩所要時間も長いいため分娩遅延による死産児の発生率が高く、ときには胎児の子宮内残留により母体の死を招くことがある。もし分娩前に胎児数の予測ができるならば、分娩の終了を確実に知りうるので遅延分娩に対する適切な早期処置が可能となり、また分娩監視に要する養豚家の労力も軽減されるものと思われる。

本研究は超音波胎児心拍動検出装置(ハートンUSD-I型: フロカ社)を用い、16頭の経産妊娠豚(大ヨークシャー、ランドレース及びハンプシャー種)について胎児数の予測を行った。実験は16頭の内15頭については最終交配後80~114日の間に各1回、また残りの1頭については最終交配後58~107日の間に5回、のべ20例につき実施した。実験の方法は供試豚の横臥安静時に無保定無麻酔のもとに、探触子を腹部の皮膚上にあてて周波数2.25 MHz、出力30 mW/cm²の超音波を照射し、胎児心拍動信号音を探索する方法によった。同時に母体心拍動信号音をも記録し、胎児心拍動信号音との判別に供した。個々の胎児を区別するには胎児心拍動信号音が探知された位置における探触子の方向及び探知され

た各位置間の距離に基づき、同または異なる胎児からの心拍動ドップラー信号音であるかを判定した。

得られた成績は次の通りである。

1) のべ20例中5例(25%)において胎児数は正確に予測されたが、残りの15例では予測胎児数と実際の分娩児数との間に-5から+3頭の誤差が認められた。

2) 予測胎児数と実際の分娩児数との誤差が±1頭の例数は20例中9例(45%)、±2頭以内の例数は20例中14例(70%)であり、そしてその誤差が±3頭以内のものは20例中17例(85%)であった。

3) 胎児数予測の正確度は最終交配後90日またはそれ以前に比べて91日以降では高い傾向が見られた($P < 0.10$)。また実際の分娩児数が9頭またはそれ以下のものに比べて10頭またはそれ以上のものでは胎児数予測の正確度は低下する傾向が見られた。

4) 本研究に用いた超音波の照射が母体及び胎児に悪影響を及ぼしたと思われる現象は全く認められなかった。供試豚のうち4頭に死産児、あるいはミイラ変性胎児の娩出が見られたが、それらの出現率は自然の発生率よりも少なかった。

以上の成績から、本法により豚における胎児数の予測がある程度可能であることを知った。また2~3頭の誤差が許されるならば胎児数診断は実用的価値があるものと思われた。

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