FETAL ELECTROCARDIOGRAM IN DAIRY CATTLE
III VARIATIONS IN FETAL QRS PATTERN

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In the previous studies of this series, the authors clarified that fetal electrocardiogram (F-ECG) is unexceptionally detectable in pregnant cattle from 5 months onward both in single and twin pregnancies[3,4]. In this study, the authors intend to make a more detailed analysis of various variations in fetal QRS (F-QRS) pattern during the period from the 5th month of pregnancy to term.

MATERIALS AND METHODS

Tracings of F-ECG used in this study were those obtained in previous studies, with the exception of one additional case of a Guernsey cow. Procedures for obtaining F-ECG were also described previously[4].

Depending on the capacity of the equipment used, only the QRS complex of fetal heart activities can be recorded, while other electrocardiographical components cannot be detected. Therefore, the main subject of this study is aimed at variations in polarity of initial deflection of the QRS and in its amplitude. The following items were selected as subjects to be discussed in this paper: 1) temporary variations in amplitude with unchanged polarity, 2) temporary disappearance of F-QRS, 3) variations in polarity and amplitude in simultaneous recordings by different leads, 4) reversal change in polarity, and 5) variations in F-QRS as pregnancy advances.

RESULTS AND CONSIDERATIONS

1) Temporary variations in amplitude with unchanged polarity

Strips a and b in figure 1 are original F-ECG papers of a short recording (approximate 14 sec) by lead 3-13 at 245 days of pregnancy, and strips a′ and b′ are traces copied from a and b, respectively. Through the whole course of these figures, F-QRS patterns are indicated as the Rs type, whose polarity of initial deflection is always on positive side. As seen in segment a, the amplitude of the first 3 beats is about 100 μV, but after O-line movement it decreases to about 30 μV, with no change in initial polarity. Likewise, in b, after severe O-line movement, Rs amplitude decreases for several seconds and returns

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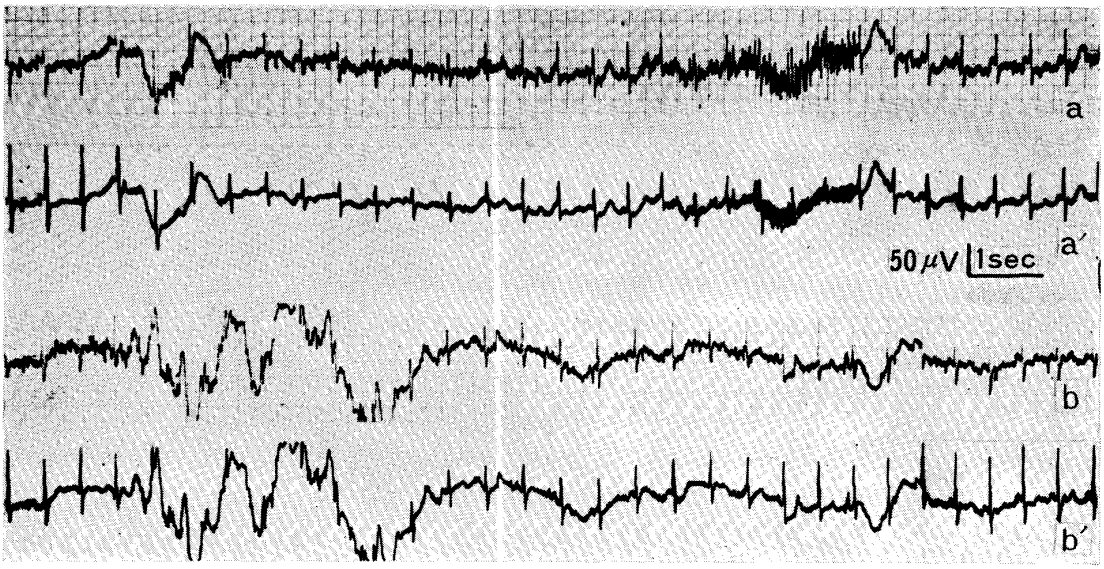
FIGURE 1 *Temporary variations in amplitude*



Notes a and b are original F-ECG papers taken at 245th day by lead 3-13.
a′ and b′ are traces from a and b, respectively.

approximately to the previous value. Similar types of variation in amplitude were frequently observed in other cases examined at different gestational stages. There are two characteristic variations in amplitude; first, such decrease in amplitude usually occurs after O-line movement, and second, variations in amplitude are reversible within a short time, and not accompanied by changes in polarity.

Such characteristic variations in amplitude may presumably be dependent upon fetal movement within a physiological range, because the O-line movement in F-ECG frequently occurs simultaneously with fetal movement in utero. In some experiments with human cases, this has been confirmed by a synchronous recording of uterine internal pressure and abdominal palpation together with F-ECG recording[2]. The main factors which may effect the degree of amplitude seem to be the distance between the electrical source (fetal heart) and lead positions, as well as the quantitative and qualitative difference in electrical disturbances (maternal muscles, viscera, fetal fluids, etc.) lying between them. The reasons why variations in amplitude are unaccompanied by a change in polarity may be due to the fact that the vector of the fetal heart against the lead plane is perhaps almost invariable in later stages of pregnancy in cattle.

2) Temporary disappearance of F-QRS

The three electrocardiograms in figure 2 are those taken by lead 1-3 at 246 days of pregnancy. In segment a, maternal and fetal spikes are clearly recognized. After a short time, there was cessation of recording because of severe disturbances by the electromyogram (EMG) and O-line movement, segment b was recorded. In b, however, no fetal spikes are observed, although maternal ones are distinct as in a. Five minutes later, segment c was recorded. This represents similar patterns with maternal and fetal spikes as in segment a.

FIGURE 2 *Temporary disappearance of F-QRS*

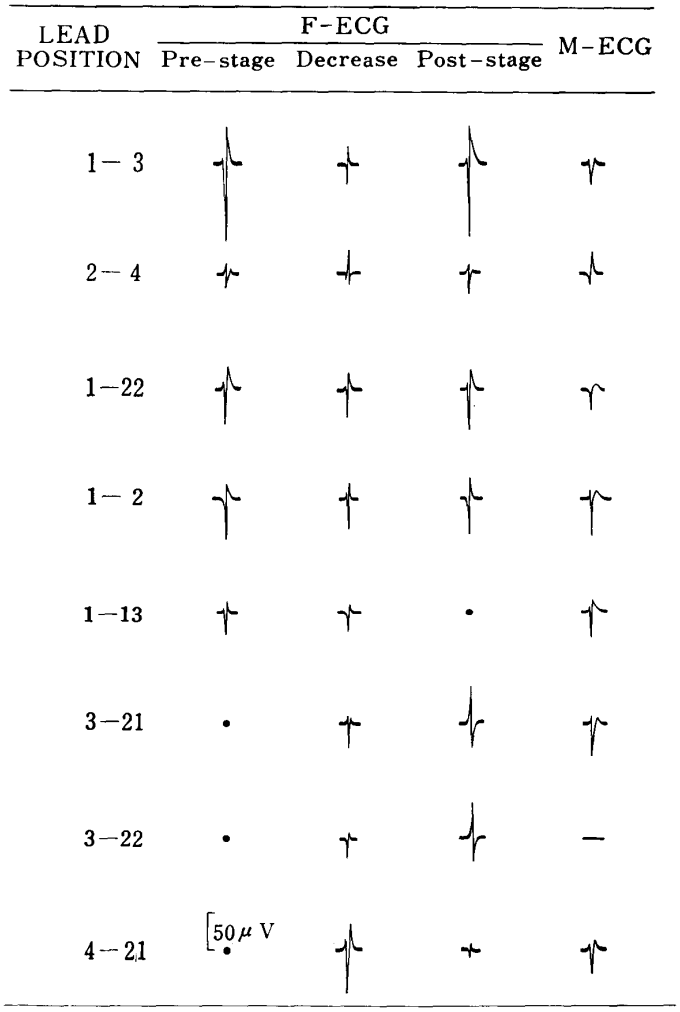
Notes f: Fetal spikes M: Maternal spikes

Why did the temporary disappearance of F-QRS in segment b happen? It can be clearly said that this phenomenon is not due to technical errors but due essentially, to the fetal side. Several factors should be considered: (1) Temporary stoppage of the fetal heart beat. (2) The distance between the fetal heart and the lead position was so great that the electrical potential of the fetal heart at the skin surface of the dam became too small to be picked up by the electrode. (3) An increase in electrical resistance due to interference of fetal fluids, etc. (4) A change in fetal heart vector, so that the angle of the vector against the lead plane became approximately 90 degrees. (5) Some electrical state in which electrical potentials on two lead points were contradicted with each other. (1) will be negligible because it is hardly thinkable that the fetal heart is able to stop for several seconds and if so, the heart activation is able to recover so promptly. Therefore, it seems reasonable to think that temporary disappearance of F-QRS may be due to fetal movement which may produce any of conditions described in (2)~(5). Furthermore, such fetal position as described in (4) may be unstable, so the fetus may promptly return to a stable position.

3) Variations in polarity and amplitude in simultaneous recordings by different leads

In one case, at 231 days of pregnancy, a sudden decrease in amplitude of the F-QRS was frequently recorded by lead 1-3. A comparison was made of variations in polarity and amplitude of F-QRS between this lead and several other leads which were carried out

FIGURE 3 *Comparison of F-QRS among several leads*



Notes • Recording was not made.
— M-ECG could not be detected.

simultaneously at the time when the decrease in amplitude took place in lead 1-3; as well as in the pre- and post-stages of the decrease. Throughout the three stages, there was no variation in maternal QRS patterns obtained by each corresponding lead, although the maternal QRS could not be detected in lead 3-22. As shown in figure 3, in leads 1-2, 1-13 and 1-22, no variation in amplitude or polarity of the F-QRS was observed throughout the three stages. Whereas, in lead 2-4, a complete inversion of polarity took place synchronously at the time when a decrease in amplitude occurred in lead 1-3. A similar inversion was also recorded in leads 3-21 and 3-22 after the decrease stage. In lead 4-21 a marked increase in amplitude was observed corresponding to the decrease stage in lead 1-3.

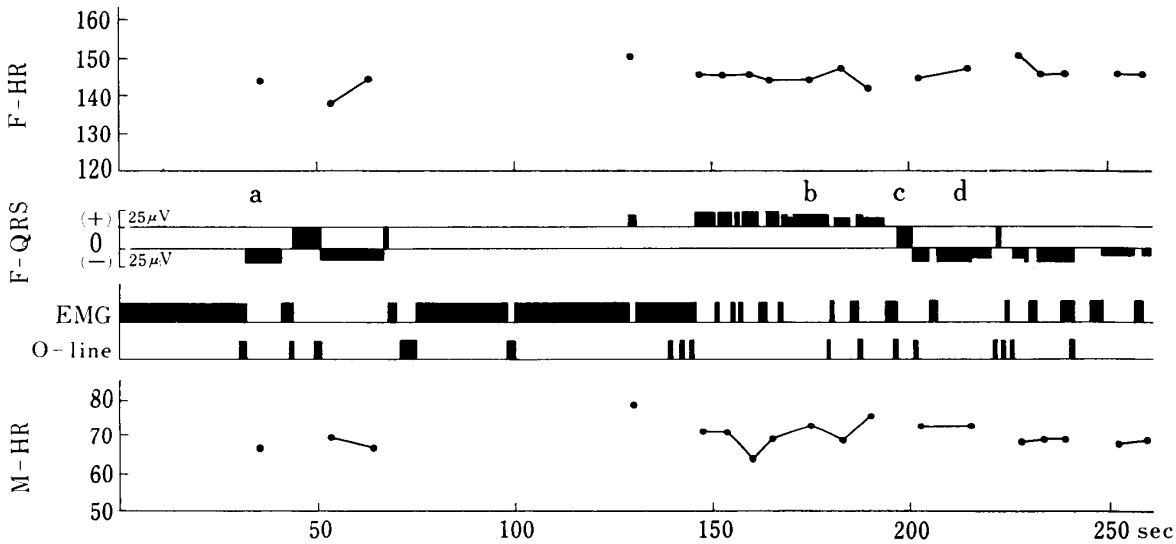
The results indicate that, when variations in amplitude or polarity are observed in a lead, the variations are also recordable by some of the other different leads at the same time. In

addition, similar patterns of the F-QRS can be seen at different stages by different leads, for example, those appearing at the pre-stage in lead 1-22 and at the decrease stage in lead 4-21, or those at the pre-stage in lead 1-13 and at the decrease stage in lead 3-21. The reasons for such a similarity on the F-QRS pattern may be due to a similar relationship between the fetal heart position and respective lead positions in both instances. However, it remains uncertain why there was no variation in the configuration in lead 1-22 throughout the three stages.

Further, the fact that a marked decrease in amplitude of the F-QRS was recorded only in lead 1-3, not in other three leads in which the lead point 1 was concerned, probably means that the electrical potential of the fetal heart would exert more effectively to the lead point 3 than to the other three points. On the other hand, in a lead in which point 4 was concerned (lead 4-21), a marked increase in amplitude was recorded simultaneously at the decrease stage in lead 1-3. Therefore, such findings in the F-ECG would suggest occurrence of fetal movement in which the position of fetus may leave point 3 and approach point 4. From above results, these leads seem to belong to a type of semiunipolar lead in a routine ECG technique, and there point 3 may act as a different electrode while the other lead points may act as semi indifferent electrodes to fetal heart activation.

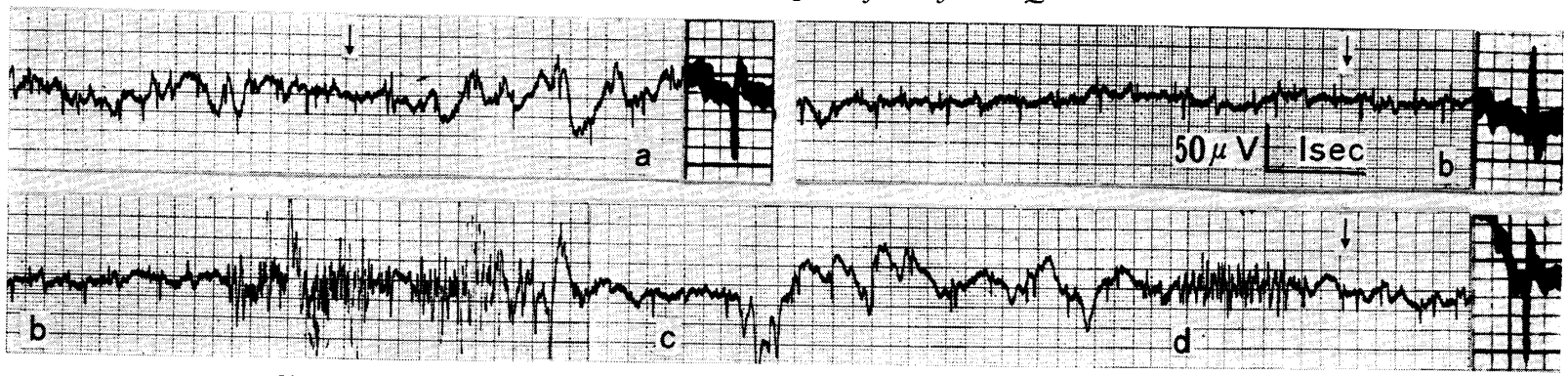
In a routine ECG technique with exception of fetal cases, it is difficult to carry out an experiment in which the heart will be allowed to change its position, because the heart is almost fixed anatomically. On the contrary, in the case of F-ECG, a fetus can move considerably freely in utero, and the fetal heart itself can take various positions against lead points on the maternal body. Therefore, it is sometimes difficult to introduce a routine ECG theory for interpretation of such a phenomenon in F-ECG.

FIGURE 4 *Long-time recording*



Notes F-HR : Fetal heart rate per minute
F-QRS : Fetal QRS
Amplitude of F-QRS is indicated by 25 μV scale.
Polarity is marked by (+) and (−).
0 means no F-ECG.
EMG : Occurrence of electromyogram
O-line : Movement of O-line
M-HR : Maternal heart rate per miunte
a~d : Same points of a~d in fig. 5

FIGURE 5 *Reversal change in folarity of F-QRS*



Notes: a~d represent the corresponding segments to those shown in figure 4.
Photographic enlargements (right) are derived from 3 parts indicated by arrows.

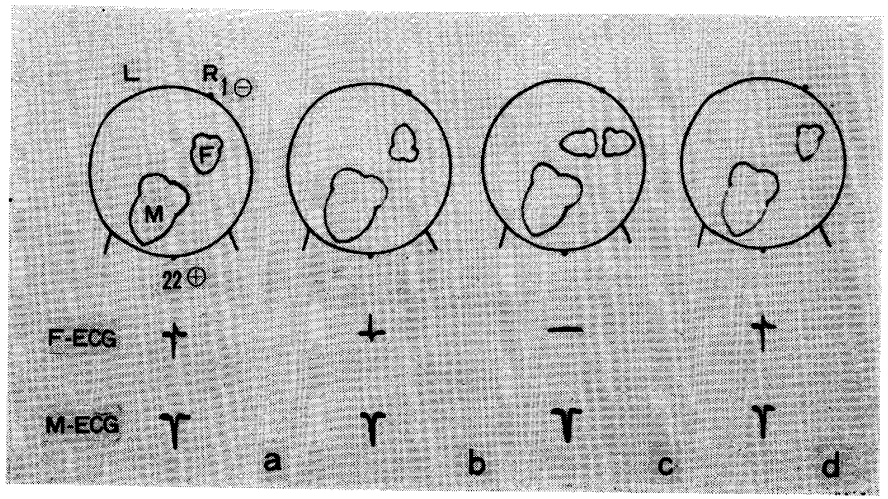


FIGURE 6 *Schemata of supposed positional changes of fetal heart*

Notes
L: Left side
R: Right side
1⊖, 22⊕: Lead points
F-ECG: Fetal electrocardiogram
M-ECG: Maternal electrocardiogram
F: Fetal heart position
M: Maternal heart position

4) Reversal change in polarity of F-QRS

This phenomenon was observed at 180 days of pregnancy during a long recording of F-ECG with lead 1-22 (figs. 4 & 5). In a continuous recording, variations in amplitude and polarity of F-QRS were observed. As shown in figures 4 and 5, in segment a, pattern of F-QRS showed Qr type and about 20μV in amplitude. After a short time disturbance of the maternal EMG, the pattern of F-QRS reversed to Rs type with a slight change of amplitude in segment b. In a serial segment including c and d, a complete reduction of F-QRS was recorded. In segment d, however, the F-QRS recovered the Qr type and was the same as that of segment a, and continued the pattern onward. On the other hand, no change was observed in amplitude and polarity of maternal QRS during the recording. In addition, no marked variation in fetal and maternal heart rates was recorded.

If a hypothesis that the principal mechanism of heart activation is the same both in fetal and maternal hearts is reliable, from the above mentioned results, the causation of the reversal change of polarity of the F-QRS will be explained as follows: In a vertical lead to the maternal body, such as lead 1-22, when the polarity of the F-QRS coincides with that of the maternal one, the apex of the fetal heart should be in a downward direction, as shown in schema a in figure 6, corresponding to segment a in figure 5. In segment b, however, polarity of the F-QRS was reversed. It is supposed that the fetal heart apex should be directed upward, i. e. to the opposite direction of the apex of the maternal heart, as shown in schema b. In segment c, the F-QRS disappeared. This probably means that the fetal heart axis should make an approximate right angle to the lead plane of lead 1-22, where the fetal heart apex should be directed to either the left or the right. Finally, in segment d, in which polarity of the F-QRS recovered to that of segment a, the fetal heart should return again to the former position in segment a. However, it is uncertain whether direction of the fetal heart movement during the above mentioned course was either clockwise or counter-clockwise.

At any rate, a fetus of about 6 months pregnancy seems to be capable of variation in its position in the uterus to the extent at 180° or more and promptly able to return to the former position. Such fetal movement should be considered to be physiological, because the movement is reversible within a short time and the fetal heart rate is invariable during the course of the movement.

5) Variations in F-QRS with advance in pregnancy

The variations in amplitude and polarity of the F-QRS with advances in pregnacy were studied by several limited leads with 3 cases. As shown in figures 7~9, in later stages of gestation, variations of the F-QRS were, in general, characterized by changes in amplitude, not accompanied with changes in polarity, while, in earlier stages, inversion of polarity was sometimes observed.

In order to electrocardiographically analyze the above mentioned variations in the F-QRS with advances in pregnancy, two main factors, (1) fetal heart vector and (2) fetal heart position against lead points, should be considered. Concerning these factors, the following conditions will be hypothetically presented:

(1) Fetal heart vector

1a: Direction of the fetal heart vector is invariable throughout whole gestational

period, indicating the same one as in the maternal heart.

1b: Direction of fetal heart vector is variable with advance in pregnancy.

(2) Fetal heart position against lead points

2a: Fetal heart position is invariable throughout the whole gestational period, keeping a constant relation to a given lead plane. The distance between them is in this occasion, without regard.

2b: Fetal heart position against lead points is variable with advances in pregnancy.

The above conditions may theoretically give 4 combinations as shown in the table. The combination of 1b–2b may likely occur at very early stages of pregnancy, when the fetal heart still remains in an underdeveloped state. However, such a combination may be left

FIGURE 7 *Variations in F-QRS with advance in pregnancy*

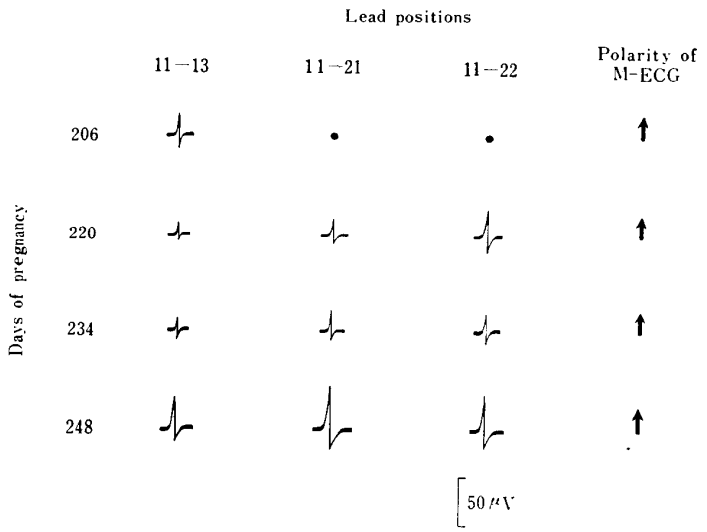


FIGURE 8 *Variations in F-QRS with advance in pregnancy*

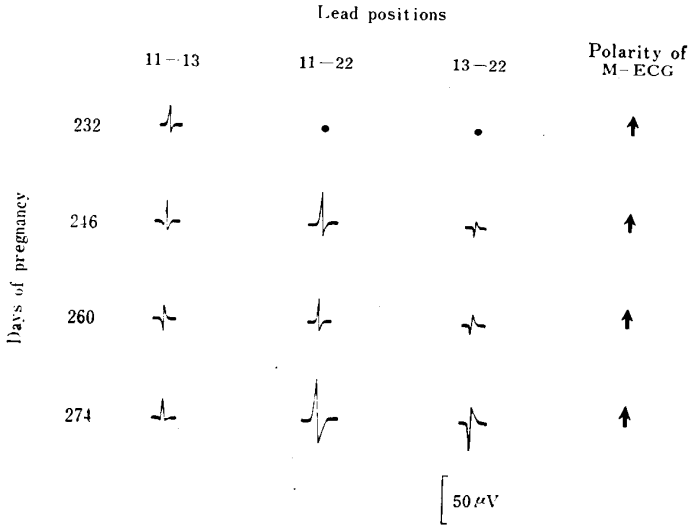


FIGURE 9 *Variations in F-QRS with advance in pregnancy*

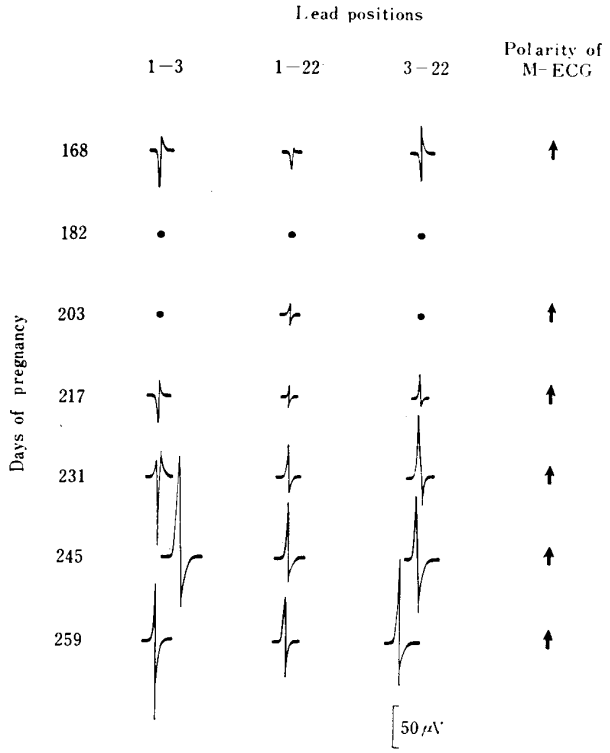


TABLE *Relationship between fetal heart vector and fetal heart position*

FETAL HEART POSITION	FETAL HEART VECTOR	
	Variable (1 b)	Invariable (1 a)
Variable (2 b)	++	+
Invariable (2 a)	+	−

Notes ++ : F-ECG may be highly effected.
+ : F-ECG may be effected.
− : F-ECG may not be effected.

out of consideration in this study, because the F-ECG cannot be recorded, at present, at such early fetal stages. The combinations of 2 a-1 b and 1 a-2 b may be adopted during the middle stages of pregnancy, where the fetal heart development is almost complete. Therefore, the vector of the fetal heart activation becomes stable, but the fetal heart position against a given lead plane may be variable due to fetal movement. So, variations in polarity of the F-QRS during the middle stages can be explained to be due to fetal movement, and not due to changes in the fetal heart vector. The combination of 1 a-2 a may occur during later stages of pregnancy, where the fetal movement may not be so great that inversion of

polarity of the F-QRS takes place, although variations in amplitude may arise.

In human cases, it has been reported that F-ECG sometimes falls or disappears during 26~30 weeks of pregnancy[1]. The causes of this phenomenon are still unknown, but the following reasons should be considered: (1) a drop in fetal cardiac source strength, (2) fetal fat development, (3) vernix development, (4) change in amniotic fluid composition, and (5) maternal change. In bovine cases of this study, such long-standing depression in F-ECG was not observed, although temporary variations or disappearance in F-ECG were sometimes recorded.

Several years ago, TOO, one of the authors, and NAKAMURA made an ECG study with young calves of 1~3 weeks postnatal. They concluded that the heart activation mechanism in newborn calves was similar to that of adult cattle[5]. As for the myocardiac activation mechanism in bovine fetuses, however, only a small amount of information is available at the present time. In the future, the development of fundamental knowledge concerning fetal anatomy and physiology in various stages of pregnancy in cattle will give us a more distinct interpretation of the mechanism.

In addition, knowledge on fetal radiography in cattle should be very important in order to analyze various phenomena in F-ECG such as those presented in this paper, particularly to clarify correlations between the variations in polarity or amplitude and fetal positional changes in the uterus.

SUMMARY

The authors intended to make more detailed analysis of various variations in fetal QRS patterns using many tracings of fetal electrocardiogram from dairy cattle during the period from the 5th month of pregnancy to term.

A temporary decrease in amplitude without changes in polarity of initial deflection of the QRS was frequently observed in later gestational stages. This variation in amplitude usually occurred after O-line movement and was reversible within a short time. So, this phenomenon may presumably be due to fetal movement.

Temporary disappearance of fetal QRS may also be principally due to some kind of fetal movement, so that the angle of fetal heart vector against the lead plane becomes approximately 90 degrees.

There were some variations in polarity or amplitude of fetal QRS between one lead and several other leads simultaneously carried out. These would suggest that the electrical potential of the fetal heart may exert more effectively on one lead point and on the other points, or that the fetus itself may leave one lead point to approach another point.

Reversal change in polarity of fetal QRS was observed in a long time recordings at middle gestational stages. This may be also caused by some changes of the fetal heart axis due to fetal movement in the uterus. Such fetal movement, however, should be considered to be physiological, because the change in polarity

of the fetal QRS is reversible within a short time and the fetal heart rate is invariable.

As for the variations in amplitude and polarity of the fetal QRS with advances in pregnancy, variations of the fetal QRS were, in general, characterized by changes in amplitude without changes in polarity in later stages of pregnancy, while in earlier stages inversion of polarity was sometimes observed. The reasons will be explained as follows: in advanced pregnancy the fetal heart development is almost completed and its activation mechanism become stable, but fetal heart position may be effected by physiological fetal movement.

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REFERENCES

1) CAUGHEY, A. F. & KROHN, L. H. (1963): *Am. J. Obstet. & Gynec.*, **87**, 525
2) HON, E. H. & LEE, S. T. (1963): *Ibid.*, **87**, 804
3) KANAGAWA, H., TOO, K., KAWATA, K. & ONO, H. (1965): *Jap. J. vet. Res.*, **13**, 111
4) TOO, K., KANAGAWA, H. & KAWATA, K. (1965): *Ibid.*, **13**, 71
5) TOO, K. & NAKAMURA, R. (1958): *Anim. Husb., Tokyo*, **12**, 975 (in Japanese)