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FETAL AND MATERNAL ELECTROCARDIOGRAMS DURING PARTURITION IN A MARE*¹

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For several years, the present authors carried out a serial study of fetal electrocardiogram in dairy cattle^{5,6,12,13}). In the latest article of this series, the authors handled the problem of fetal and maternal heart activities associated with parturition¹⁴). From the standpoint of obstetrics in large domestic animals, many lives of fetuses are jeopardized at parturition in horses as well as cattle. However, to the authors' knowledge, no article has been reported on fetal electrocardiographical study during parturition in horses. This led the authors to attempt to carry out the present study. As this preliminary report is based on the findings of only one case, more cases should be added in the future to confirm the conclusion.

MATERIAL AND METHODS

A seven-year-old half bred mare at full term was subjected to this experiment. At the 336th day of pregnancy, a healthy female foal was delivered under normal conditions with fetal vertex presentation and prone position. The actual time required for delivery was about 30 minutes.

Recordings of fetal electrocardiogram (F-ECG) before parturition were made at the 316th and 335th days of gestation, by means of a bipolar lead between the right flank and the lower abdomen on the maternal skin surface. An electrocardiograph, TOF-1500*³ was used. After symptoms of the initiation of parturition appeared, fetal and maternal electrocardiograms were continuously recorded until the afterbirth was expelled. Electrocardiograms of the newborn and of the mother were recorded by the routine ECG method.

RESULTS

1 Changes in heart rates of fetus, dam and newborn

Changes of fetal heart rate (F-HR), maternal heart rate (M-HR) and newborn's heart rate

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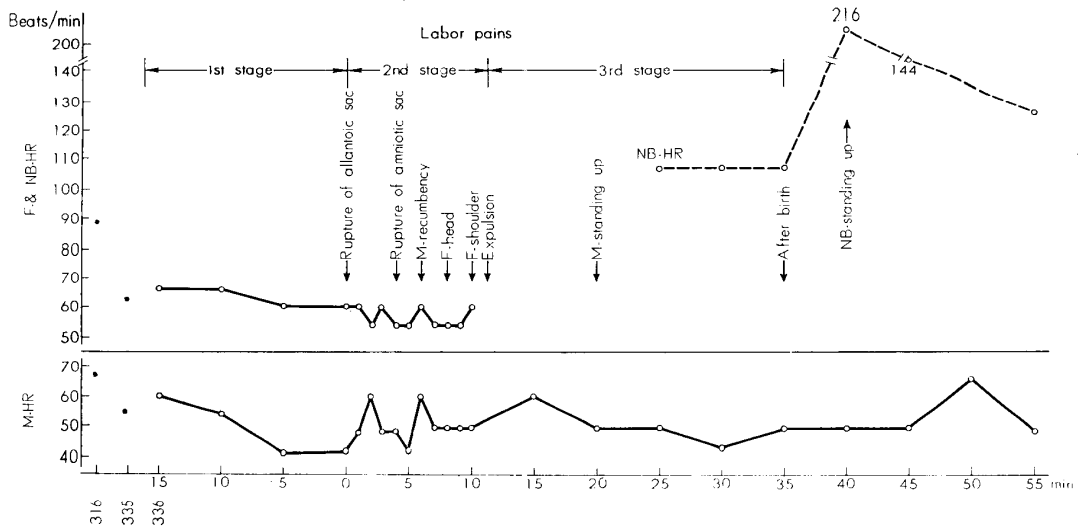
*³ Manufactured by the Fukuda Electro Co. Ltd., Tokyo, Japan

TABLE Changes of maternal and fetal heart rates during parturition

DAY OF PREGNANCY	TIME	MATERNAL HEART RATE	FETAL HEART RATE	LABOR PAINS	REMARKS	
316	14:00	68	89			
335	11:00	56	62			
336	20:20	60	66	1st stage →		
	20:25	54	66			
	20:30	42	60			
	20:35	42	60			Rupture of allantoic sac
	20:36	48	60			
	20:37	60	54	← 1st stage	Appearance of amniotic sac	
	20:38	48	60	↑		
	20:39	48	54		Rupture of amniotic sac	
	20:40	42	54			
	20:41	60	60	2nd stage	Mother lying	
	20:42	54	54			
	20:43	54	54			
	20:44	54	54		Exposure of fetal head	
	20:45	54	60		Exposure of fetal shoulders	
	20:50	60	—	←	Expulsion of fetus	
	20:55	54	—	↑	Mother standing	
	21:00	54	108*	3rd stage		
	21:05	48	108*			
	21:10	54	108*			
	21:15	54	216*	↓	Expulsion of afterbirth	
21:20	54	144*		Newborn standing		
21:25	66	—				
21:30	48	126*				

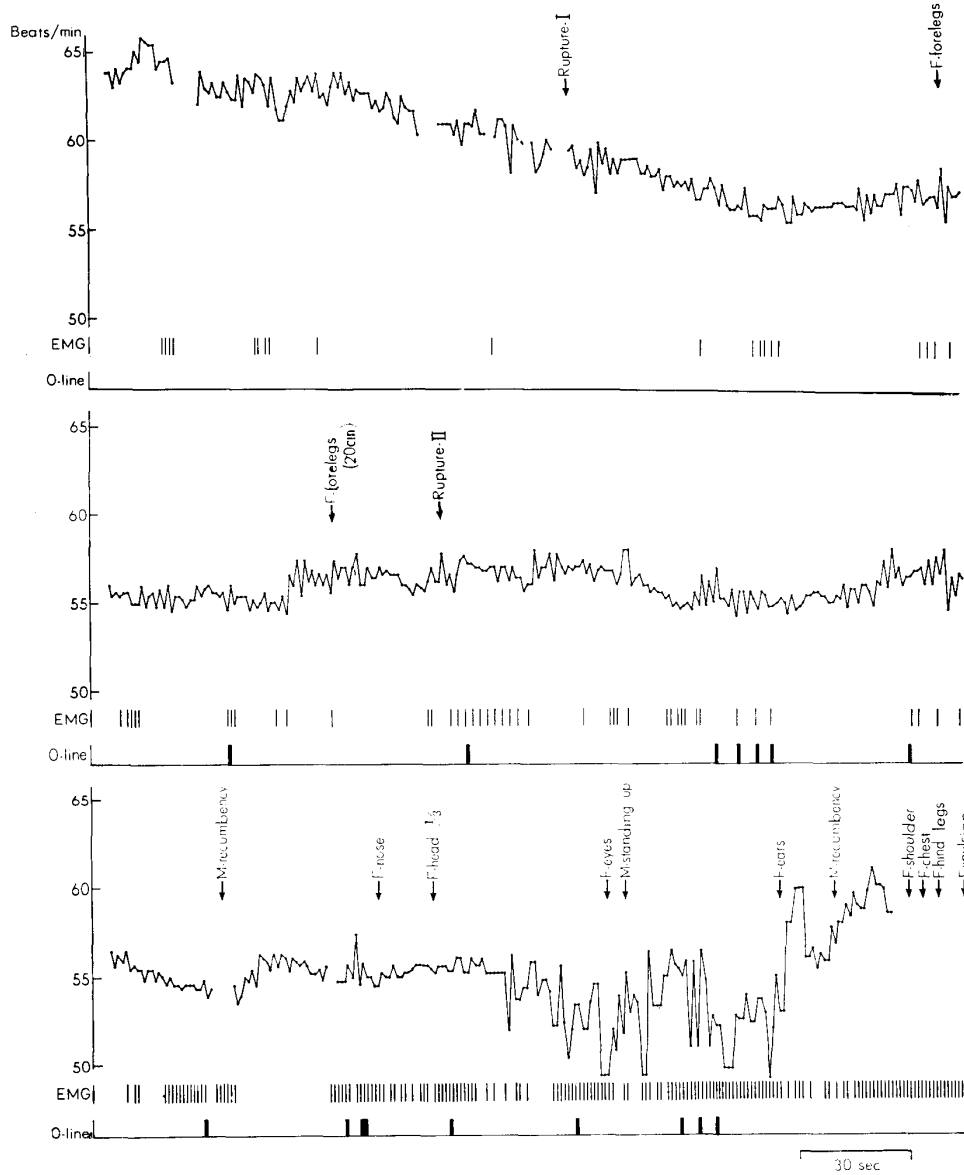
Notes *: Heart rate of newborn —: Missing data

FIGURE 1 Changes of heart rate during delivery



Notes F-HR : Fetal heart rate NB-HR : Newborn's heart rate
M-HR : Maternal heart rate 316, 335 and 336 mean fetal ages.

FIGURE 2 Diagram of fetal Q-Q (R-R) interval during parturition



Notes Successive recordings

EMG: Maternal electromyogram on ECG tracing

O-line: 0-line movement on ECG tracing

(NB-HR) in each observation period are shown in the table and figures 1 and 2.

The F-HR, at the 316th day after copulation, was calculated as 89 per minute. This value decreased to 62 at the 335th day, one day prior to parturition. Immediately before the beginning of parturition F-HR was counted as 66. For approximately 15 minutes of the first stage of labor, it varied from 54 to 66. At the second stage of labor the value decreased to 54~60 until the shoulders of the fetus were exposed. Thus F-HR maintained a low level during the whole course of parturition (fig. 2). When the fetal eyes and ears were exposed,

fetal Q-Q intervals became irregular. Bradycardia, associated with each uterine contraction phase was not observed.

Recording of the newborn's ECG was started 10 minutes after expulsion of the fetus. When the newborn foal was still lying NB-HR was 108, but as she began to stand up it rapidly increased to 216 and then gradually decreased to 126~144. These values corresponded to about 2~4 times as great as those before expulsion.

During the period from the initiation of labor pains to 30 minutes after expulsion of the fetus, M-HR was comparatively lower, ranging from 42 to 60. However, marked arrhythmia which may have been caused by ventricular drop was sometimes observed.

2 Changes in patterns of fetal QRS and of maternal QRS

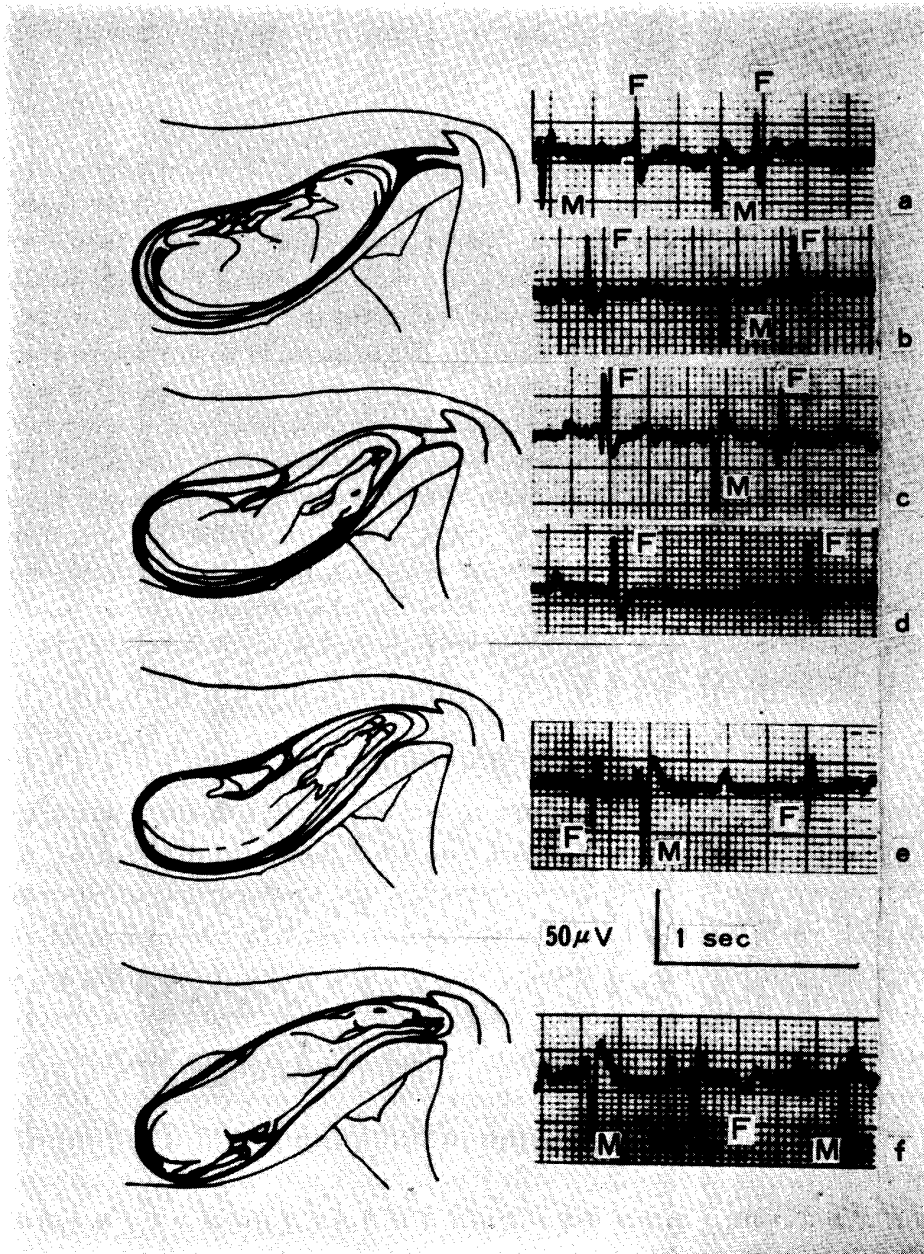
Throughout the entire observation course, the pattern of maternal QRS (M-QRS) did not indicate any remarkable change. It usually showed a negative pattern as to QS type. No correlation was observed between parturition and the maternal ECG pattern.

On the other hand, changes of fetal QRS (F-QRS) pattern in the respective labor stage were very characteristic. First of all, at the 316th day, F-QRS pattern showed Rs type; the polarity of the initial deflection of F-QRS indicated the opposite direction against that of M-QRS (fig. 4). From this, the fetal position in the uterus is assumed to be ventral as shown in Figure 3-a. A similar QRS pattern was also recorded at the 335th day (figs. 3-b & 5). From the commencement of the first stage of labor to rupture of the amniotic sac, 10 minutes had passed. During the period F-QRS showed 2 different patterns, qRS and Rs (figs. 3-c, d & 6-a~c). These QRS variations may be due to fetal movement caused by uterine contraction. However, the main position of the fetus remained without change from the ventral position. When labor was gradually accelerated, F-QRS pattern changed to QR type (fig. 6-d) accompanied by a reduction of its amplitude. This pattern continued for 60 seconds. The fetal position during the period is assumed to be lateral as shown in figure 3-e. Then, suddenly, the QRS type changed to Qr type within 1 second (fig. 6-e: arrow), where the polarity of the initial deflection indicates the same direction as that of maternal one. This should be indicative of the fact that the fetal position become dorsal as illustrated in figure 3-f. Two minutes later, the amniotic sac ruptured. No further change of F-QRS pattern was observed until the fetus was delivered. This fact means that the fetal position became stable because the majority of the fetal front portion had already entered the birth canal. When the fetal shoulders appeared, F-ECG became impossible to record, although M-QRS was still clearly detected (figs. 6-g & h).

3 Labor pains recorded on ECG tracings

Electromyograms (EMG) of the abdominal muscles associated with labor attacks were recorded on ECG tracings. At the first stage of labor, a slight deflection of ECG 0-line and a group of EMG with small amplitude and irregular intervals were recorded (fig. 6-b). During the second stage of labor, clear EMG groups with large amplitude regularly appeared every 1~2 seconds (figs. 6-f & g). There was no marked difference between EMG taken at the time when the mother was standing (fig. 6-f) and that taken when she was lying (fig. 6-j). After the fetus was delivered, irregular EMG spikes with small amplitudes were sometimes recorded until the afterbirth was expelled.

FIGURE 3 Changes of fetal and maternal QRS patterns



Notes F: Fetal spikes
M: Maternal spikes
Fetal positions were modified from STOSS.

4 Arrhythmia of maternal heart rhythm

Throughout the whole course of parturition of this case, ventricular drop of maternal heart beats was frequently recorded. This ventricular drop was characterized by incomplete

A-V block which sometimes appears also in ECG taken from non-gravid mares. The A-V block usually occurred once per 6~8 heart beats during the early stage of the course of parturition (fig. 6-i: arrow & fig. 3-d), but it become more frequent during the later phase of the 3rd stage of labor (fig. 7).

5 ECG of the newborn foal

Ten minutes after expulsion of the fetus, the newborn's ECG could be recorded by means of both bipolar and unipolar leads on the skin surface. In a bipolar lead from the chest wall, a sharp form of the P wave and a deep T wave were obtained (figs. 8-a~c). In a unipolar lead from the apical portion of the heart, the deflection of the QRS usually indicated downward (fig. 8-d), while in another unipolar lead from the basal portion of the heart the deflection of the QRS become upward (fig. 8-e). These patterns from unipolar leads are quite similar to those in the case of adult animals. This means that the activation mechanism or process in the ventricular wall of the newborn foal coincides with that of adult horses. That is, the heart activation mechanism in both cases has an apico-basal direction. Therefore, it is theoretically agreeable that the fetal position in the uterus can be presumed by comparison with the polarity of the initial deflection of F-QRS with that of M-QRS, i.e., if the polarity of the initial deflections of F- and M-QRS are the same, the fetal position in utero may be dorsal, while if the deflections are opposite each other, the fetus may have a ventral position. This hypothesis, however, may be applicable only to the bipolar lead between the right flank and the lower abdomen.

DISCUSSION

This article is presumably the first report of F-ECG during parturition in the horse. In human medicine, many works on fetal heart rhythm during parturition have been carried out^{2~4,7)}. The occurrence of bradycardia of human fetuses associated with each labor pain and with fetal distress has been considered as one of characteristic fetal responses during parturition. The mechanism of such fetal bradycardia has been hypothetically interpreted as the result of a disturbance of maternal-fetal blood circulation which is caused by contraction of the uterine myometrium. Another hypothesis should be also presented as to myocardio-cerebral affiliation. Likewise, in the observations of dairy cattle fetuses¹⁴⁾, temporary bradycardia associated with labor pains was frequently recognized.

On the other hand, in this experiment, the heart rate of a horse fetus showed a decreasing tendency with acceleration of labor pains and with progress of the course of parturition, then it recovered the initial value after the fetal shoulders were exposed. Such decrease of F-HR which appeared in the earlier stage of parturition may be interpreted by the hypothesis of HON²⁾, however, the phenomenon, a recovery from irregularity, which occurred in the later stage when more severe labor pains were attacking the mare, may not be explained clearly by the maternal-fetal circulation disorder.

The drop of maternal ventricular beat which was electrocardiographically characterized as incomplete A-V block was frequently recorded during and after expulsion of the fetus. Presumably, the principal cause of the drop may be a reflex activation of the vagus induced by the labor. In fact, in the horse, such an A-V block can be easily produced by slight stimulation of the nose¹⁾ and severe abnormalities in ECG are frequently recorded during attack of colic¹¹⁾. These abnormalities of the heart beat are usually reversible in nature, disappearing with the removal of the causal agents.

According to the text book by STOSS, the typical fetal positional change in the uterus of the mare during parturition, i. e., an interchange from supine position to prone position, is interpreted to be an important mechanism which facilitates expulsion of the fetus. The electrocardiographical observations of this experiment are highly suggestive of the reasonableness of the description. If the interchange mechanism of the fetal position in uterus is disturbed, normal parturition must not be expected. So, the fetal electrocardiographical technique may be helpful for watching the course of parturition in horse obstetrics as well as in human medicine. On the contrary, in some cases of dairy cattle¹⁴⁾, a reversal change of F-QRS, $R_s \rightarrow rS_r$ frequently occurred before rupture of the bag without relation to maternal position. After rupture, F-QRS pattern always showed R_s type. However, in the case of the horse, such change in F-QRS pattern was not recorded. It was characterized by an irreversible pattern—"step by step"—according to progress of parturition. To the above described difference between both animals on the change in the F-QRS pattern, the authors cannot offer a reasonable explanation.

On the basis of the findings of this experiment using unipolar methods, the process of ventricular activation in the newborn's heart seems to coincide with that of the heart of adult horses, in which ventricular activation usually takes an apico-basal direction^{8,9)}. Therefore, this may give a fundamental basis for diagnosing fetal position in the uterus both in late stages of pregnancy and during parturition.

SUMMARY

Fetal, maternal and newborn electrocardiograms were studied on a seven-year-old mare during the entire course of normal parturition.

A summary of the results is as follows:

- 1) The fetal heart rate indicated 60~66 beats per minute before the onset of parturition, and it declined a little with the commencement of the first stage of labor, keeping a level of 54~60 until the fetus was expelled. The heart rate of the newborn foal increased rapidly, ranging 108~216. These values of the newborn corresponded to about 2~4 times those before expulsion.

2) Throughout the whole course of parturition, the maternal heart rate was generally stable with a range of 48~60, but arrhythmia was sometimes observed especially at later stages of parturition. This arrhythmia was characterized by incomplete A-V block.

3) After when the fetal head was exposed, fetal Q-Q intervals become highly irregular.

4) Characteristic changes of the pattern of fetal QRS were recognized at respective labor stages during parturition: Rs type before the onset of labor pains, types of qRS, Rs and QR from the commencement of the first stage of labor to 2 minutes before rupture of the amniotic sac, and Qr type immediately before the rupture. Relationships between these types of fetal QRS and fetal positions in the uterus were also discussed from the viewpoint of obstetrical use of ECG during parturition of the horse.

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EXPLANATION OF PLATES

PLATE I

- Fig. 4 Fetal electrocardiogram at 316 th day of pregnancy
F : Fetal spikes
M: Maternal spikes
- Fig. 5 Fetal electrocardiogram at 335th day of pregnancy
- Fig. 6 Fetal electrocardiograms during parturition at 336th day of pregnancy
- a: Recording before onset of labor pains (time : 20 : 20)
 - b: Commencement of 1st stage of labor (arrow, time : 20 : 25)
 - c: Before rupture of allantoic sac (time : 20 : 30)
F-QRS showing Rs type
 - d: F-QRS pattern changes to QR type (time : 20 : 38).
 - e: One minute before rupture of amniotic sac (time : 20 : 38)
d and e are continuous strips.
Arrow indicates change point of F-QRS from QR to Qr.
 - f: Typical labor pains at 2nd stage (time : 20 : 42)
 - g: Exposure of fetal head (arrow, time : 20 : 44) and typical labor pains at 2nd stage
 - h: Complete expulsion of fetus (arrow, time : 20 : 50)
 - i: Ventricular dropped beat (arrow, time : 20 : 55)
 - j: Labor pains at 3rd stage and expulsion of afterbirth (arrow, time : 21 : 10)

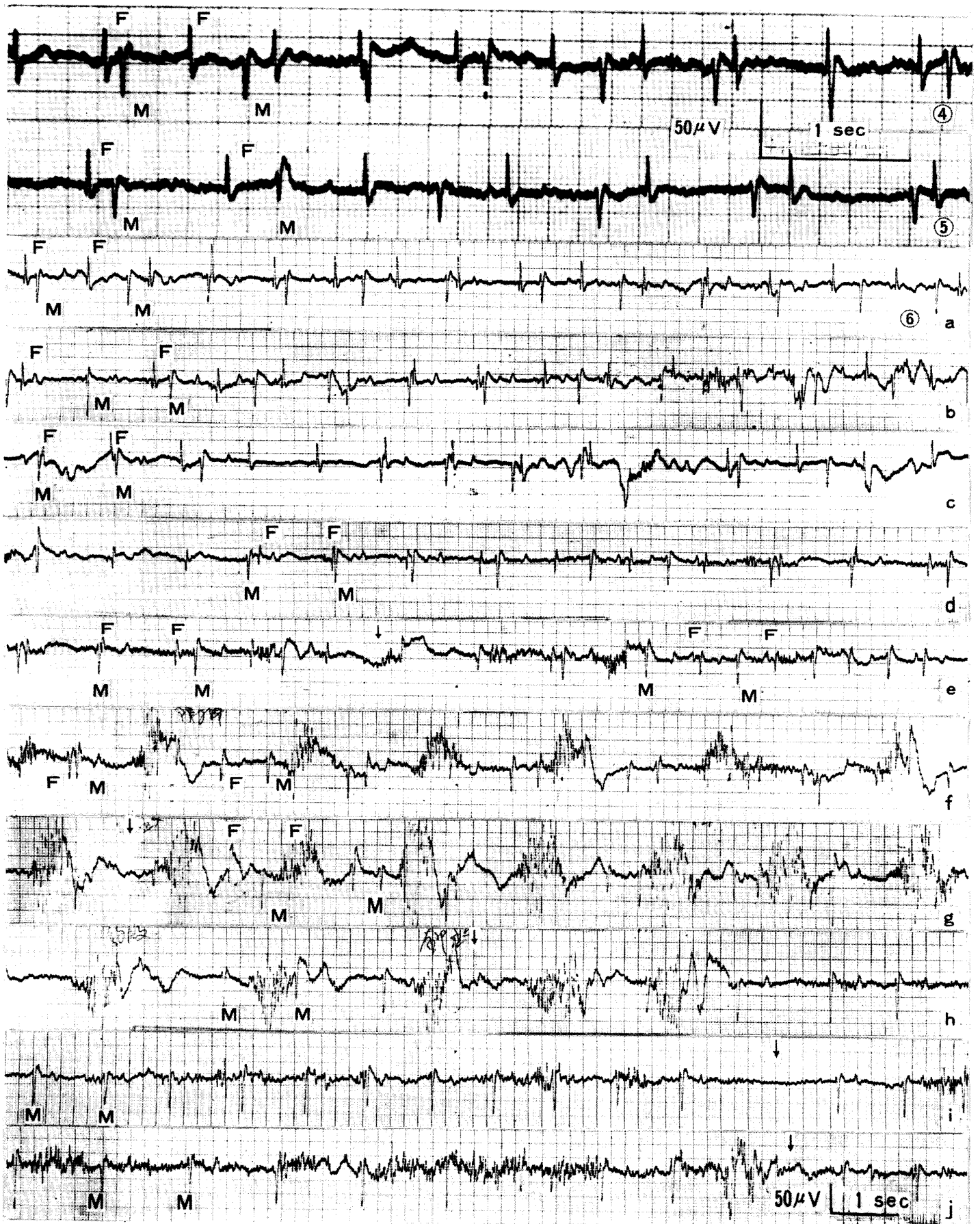


PLATE II

Fig. 7 Maternal electrocardiogram after fetus was expelled

Notes incomplete A-V block.

Arrow indicates P wave.

Fig. 8 Electrocardiograms of newborn foal

- a: Lead I
 - b: Lead II
 - c: Lead III
- } Electrodes were placed on lower chest (R), withers (L) and right flank (LF) respectively.
- d: Lead V ... Unipolar lead from skin surface at apical portion of heart
 - e: Lead V ... Unipolar lead from skin surface at basal portion of heart

