Changes in the Fetal Heart Rate of Thoroughbred Horse through the Gestation

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ABSTRACT. Fifty-nine recordings of fetal and maternal heart rate (FHR and MHR) were made from 10 pregnant Thoroughbred mares. Each recording lasted for an average of 20 min. The heart rate was calculated at an interval of 10 sec from beat to beat using the R or S wave of the fetal electrocardiograms as the indicator of each heart-beat. FHR was classified into the baseline FHR and the FHR acceleration, the latter of which was a brief tachycardia occasionally observed. The baseline FHR decreased logarithmically with the advance in gestational period, while the mean MHR increased. The frequency and the magnitude of the FHR acceleration increased at the later period of gestation, suggesting the development of fetal body movements.—**KEY WORDS:** fetal heart rate, FHR acceleration, maternal heart rate, Thoroughbred horse.

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Fetal electrocardiography in the domestic animals has been used for diagnoses of (1) life or death of fetus, (2) the occurrence of multiple pregnancy, and (3) the fetal position [1, 5, 10, 17, 18]. Extensive studies in human, recently, indicate that fetal heart rate (FHR) is applicable as a sign of fetal health state, since it changes with gestational age and is easily modified by fetal body movements including fetal breathing [2, 3, 11, 13–16, 21, 22].

A high incidence of fetal abortion is one of serious causes of reproductive failure in horses [12]. In the present study, characteristics of FHR was investigated in the Thoroughbred horse for the future use of FHR as an indicator of the fetal health in horses.

MATERIALS AND METHODS

Ten pregnant Thoroughbred mares bred in the Stock Farm of the University of Tokyo were used. The experiment was carried out between 1981 and 1983. A total of 59 recordings of fetal ECG (FECG) were made using a fetal electrocardiograph (FK-100F,

Fukuda Electro Co., Tokyo) from 6 months of gestation to the term. The FECGs were taken for 20 min at paper speed of 25 mm/sec while dams were in standing posture in a stable. One electrode was placed on a dam's abdomen and the other on the back. The recordings were carried out between 1:00 to 3:00 P.M. once a month up to 10 months of gestation and once every two weeks thereafter. At an average of 335 days of gestation [335 ± 7 days (mean $\pm$ S.D.), $n=10$], the dams gave normal births to 3 colts and 7 fillies.

The FHR or MHR (beats/min) was calculated at an interval of 10 sec using the RR or SS interval as the indicator of each heart-beat.

The baseline FHR [22] was defined in this study as the mean of the FHR for 5 min when FHR was most stable during a 20 min recording period. A transient increase of the FHR (a brief tachycardia) was occasionally observed during a 20 min recording period, which was defined as the FHR acceleration according to Wheeler and Murrills [22], where the heart rate increased above the baseline FHR for 30 sec or a longer period with a minimal

Fig. 1. Representative diagrams of FHR, MHR and FECG at 329-day of gestation. The first half of the FHR diagram shows the baseline FHR, and the latter one includes the FHR acceleration. The FECGs of 60 and 500 sec correspond to the baseline FHR, and those of 680, 1000 and 1010 sec to the FHR acceleration. The FECG panels of 680 and 1000 sec are continuous tracing. The deflections of the fetus (•) and mare (○) are shown in the FECG.

increase of 10% of the baseline FHR. The baseline FHR, the maximum FHR acceleration (a percent increase of the highest FHR above the baseline FHR) and the appearance rate of FHR acceleration period (percent of the total FHR acceleration period/total observation period) were measured from each FHR diagram. As MHR was less variable than FHR, it was presented as the mean value of MHR during 20 min (the mean MHR).

RESULTS

A representative diagram of the FHR and MHR at 329-day of gestation during a 20 min

period plotted at an interval of 10 sec are presented together with several arbitrary selected parts of a FECG recording (Fig. 1). The level of FHR was always higher and varied in larger magnitude than MHR. A transient increase of the MHR corresponded to mother's body movements due to noise, insects etc. The fetal QRS complexes and the isoelectric line did not show any observable change when FHR stayed at the baseline (FECGs at 60 sec and 500 sec). On the contrary, the fetal QRS complexes obviously changed in the configuration and the amplitude, and the isoelectric line moved wavyly when FHR was accelerated (FECGs at 680

Fig. 2. Changes in baseline FHR and mean MHR during a gestational period. Day 0: day of parturition. The baseline FHR ($\circ$) decreased logarithmically ($y=55.16+23.86 \log^{-x}$, $x=\text{days}$). The mean MHR ($\bullet$) increased logarithmically ($y=53.78-7.27 \log^{-x}$, $x=\text{days}$).

Table 1. The coefficient of variation in the FHR and some parameters concerning with the FHR acceleration during gestational period

Days before parturition	Number of records	Coefficient of variation in FHR (%)	Maximum FHR acceleration (%) ^{a)}	Appearance rate of FHR acceleration (%) ^{b)}
-157~-121	5~9	$5.72 \pm 1.00^c)$	29.3 ± 7.26	18.3 ± 7.26
-120~-91	5~8	4.79 ± 0.53	17.2 ± 3.10	9.9 ± 5.47
-90~-61	7~9	8.33 ± 1.24	42.7 ± 8.17	26.0 ± 5.46
-60~-31	12	7.55 ± 1.13	29.7 ± 5.37	20.9 ± 4.71
-30~-1	21	9.69 ± 0.74	45.2 ± 5.35	26.5 ± 4.48

a) maximum % increase from the baseline FHR.

b) total FHR acceleration period/total observation period (%).

c) mean $\pm$ SEM.

sec, 1000 sec and 1010 sec).

Fig. 2 indicates changes in the baseline FHR and the mean MHR with the advance in gestational period. The baseline FHR decreased logarithmically (110 beats/min at 150 days before the term and 75 beats/min near the term). In 3 cases recorded immediately

before parturition, FHR was 60 to 65 beats/min. The mean MHR, in contrast, increased logarithmically with the advance in gestational period.

Table 1 demonstrates the coefficient variation of FHR, the maximum FHR acceleration, and the appearance rate of FHR acceleration

period at various gestational periods. These 3 parameters tended to increase at the later period of gestation.

DISCUSSION

It is generally accepted that the FHR tends to decrease in large mammals but increase in small mammals with the advance in gestational period [8]. The decrease in FHR with the advance in gestation has been observed in horses [1, 5, 7, 9], cattle [7, 9, 17], pigs [18], sheep [6, 19] and human [20, 21], and the decreasing rate can be generally expressed by a linear equation. A logarithmic decrease in the baseline FHR has not been published.

Llanos *et al.* [6] and Walker *et al.* [19] have reported that a decrease in the FHR of lambs resulted from either a progressive increase in the parasympathetic activity or a progressive decrease in the sympathetic activity with the advance in gestational period. The logarithmic decrease in the baseline FHR in the Thoroughbred horse might be related to a specific alteration of the activity of the fetal autonomic nervous system.

FHR is influenced by the fetal body movements [2, 3, 13]. By an ultrasonic observation for the fetal body movements in the horse, Fraser *et al.* [4] reported that the incidence of complex fetal body movements increased from approximately 6 times/hour at 10 months of gestation to 20 times/hour at 11 months of gestation. According to their observation, the length of FECG recording was set for 20 min to obtain an indirect evidence for fetal body movements. Changes in the configuration and the amplitude of the fetal QRS complex and fluctuations of the isoelectric line during the FHR acceleration period strongly suggested that the FHR acceleration was associated with the change in the fetal position and/or fetal body movements. Consequently the frequency of the FHR acceleration can be used as an indicator of fetal activity. However, it is still not clear how

each fetal body movement triggered the FHR acceleration pattern which varied in duration from 30 sec to 8 min and in magnitude from 10% to 108%. It is necessary to use both the fetal electrocardiograph and the ultrasonic observation simultaneously in future.

The mean MHR may be a useful indicator for the maternal health, as it is assumed to increase with the advance in gestational period due to the increased requirement for the placental circulation. It was suggested that a simultaneous recording of FHR and MHR is available for indicating the fetal and maternal health during gestation.

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要 約

サラブレッド胎仔の胎齢の進行にともなう心拍数の変化：松井寛二・菅野 茂¹⁾・増山いずみ¹⁾(東京大学農学部附属牧場, ¹⁾家畜環境生理学教室)——11頭の妊娠サラブレッドの妊娠経過を追って、のべ59例の胎仔心電図を20分間にわたり記録し、妊娠時の胎仔心拍数ならびに母体心拍数の変化を調べた。基線胎仔心拍数(baseline FHR)は妊娠の進行にともなって対数関数的に減少し、平均母体心拍数は逆に増加した。胎仔心拍数の変動係数、胎仔心拍数一過性頻脈(FHR acceleration)の大きさおよびその出現頻度は妊娠の進行にともなって増加傾向にあり、胎仔の自発運動などの活発化を示唆していた。