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Heart rate and heart rate variability in pregnant dairy cows and their fetuses determined by fetomaternal electrocardiography

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ABSTRACT

In this study, fetomaternal electrocardiograms were recorded once weekly in cattle during the last 14 weeks of gestation. From the recorded beat-to-beat (RR) intervals, heart rate and heart rate variability (HRV) variables standard deviation of the RR interval (SDRR) and root mean square of successive RR differences (RMSSD) were calculated. To differentiate between effects of lactation and gestation, pregnant lactating (PL) cows (n = 7) and pregnant nonlactating (PNL) heifers (n = 8) were included. We hypothesized that lactation is associated with stress detectable by HRV analysis. We also followed the hypothesis that heart rate and HRV are influenced by growth and maturation of the fetus toward term. Maternal heart rate changed over time in both groups, and in PL cows, it decreased with drying-off. During the last 5 weeks of gestation, maternal heart rate increased in both groups but was lower in PL cows than in PNL heifers. Maternal HRV did not change over time, but SDRR was significantly higher in PL cows than in PNL heifers, and significant interactions of group × time existed. On the basis of HRV, undisturbed pregnancies are thus no stressor for the dam in cattle. Fetal heart rate decreased from week 14 to week 1 before birth with no difference between groups. Gestational age thus determines heart rate in the bovine fetus. The HRV variables SDRR and RMSSD increased toward the end of gestation in fetuses carried by cows but not in those carried by heifers. The increase in HRV indicates maturation of fetal cardiac regulation which may be overrun by high sympathoadrenal activity in fetuses carried by heifers as suggested by their low HRV.

1. Introduction

Lactation leads to high energetic demands in dairy cows (reviewed by [1]). High lactational performance requires adaptational changes of the cardiovascular system and may constitute a chronic stressor for animals. In late gestation, the increasing demands of the growing fetus represent an additional burden for the maternal metabolism. When immature ewes become pregnant, they preferentially partition nutrients toward their own growth at the expense of placental and fetal development. High metabolic demands in the mother may thus affect fetal well-being and outcome of pregnancy [2–4].

Hypoxia endangering the fetus is a major problem of most pregnancy disorders. Oxygenation of the fetus depends on placental oxygen supply, and a reduction in fetal cardiac activity is the only possibility to reduce oxygen consumption. The primary response to fetal hypoxia is thus a reduction in heart rate. Fetal movements are associated

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with a transient increase in heart rate, and episodic heart rate increases are indicative of fetal well-being. A lack of episodic heart rate accelerations suggests reduced activity in compromised fetuses [5–7].

Cardiovascular function in the pregnant cow and in its fetus can not only be studied from heart rate recordings but also by analysis of heart rate variability (HRV), i.e., short-term fluctuations in heart rate. The HRV reflects the oscillatory antagonistic influence of the sympathetic and parasympathetic (vagal) branch of the autonomic nervous system (ANS) on the sinus node of the heart, and HRV recordings allow analysis of the response of the ANS to stress. A decrease in HRV indicates sympathetic dominance, whereas HRV increases with high parasympathetic tone [8]. In humans, fetal HRV rises markedly after week 30 of gestation, reflecting maturation of the ANS control of cardiac activity [9,10]. Reduced HRV is considered a sign of fetal compromise [11]. No studies on HRV in the bovine fetus are available so far.

Fetomaternal electrocardiography allows continuous recordings of fetal and maternal heart rate during pregnancy. With the availability of portable electrocardiogram (ECG) recorders, fetomaternal electrocardiography has recently become available for large animals but so far has near-exclusively been used in horses [12–14]. However, the technique is also of interest in cattle, both for research and clinical use.

In this study, we have recorded fetal and maternal ECGs in cattle during the last 14 weeks of gestation. From the recorded cardiac beat-to-beat (RR) intervals, heart rate and HRV variables standard deviation of the RR interval (SDRR) and root mean square of successive RR differences (RMSSD) were calculated. It was the aim of the study to detect changes in the regulation of maternal and fetal cardiac activity over time and to establish normal values in undisturbed pregnancies. To differentiate between effects of lactation and gestation, pregnant lactating (PL) cows and pregnant nonlactating (PNL) heifers were included. We hypothesized that lactation is associated with a stress response detectable by HRV analysis and such a response is lacking in nonlactating pregnant animals. We also followed the hypothesis that fetal heart rate and HRV monitoring provide information on the developmental stage of the fetal ANS and allow the examination of fetal well-being in cattle.

2. Materials and methods

2.1. Animals

A total of 15 Austrian dairy dual-purpose Simmental cows and heifers from the Research and Teaching Farm of the Vienna University of Veterinary Sciences were included in the study and allocated to two groups. Pregnant lactating cows (PL, n = 7) formed one group. Gestational length in PL cows was 284.0 ± 2.1 days. The age of cows at calving was 54.6 ± 6.6 months, and the mean number of lactations was 2.9 ± 0.4 (mean ± standard error of the mean [mean ± SEM]). The animals were housed in groups in a freestall barn and milked twice daily. Average milk yield in the herd was 8100 kg per 305 days of lactation. Group PL cows were fed according to their requirements for maintenance and production with high-quality roughage (maize silage, grass silage, hay) and concentrates. Minerals and water were freely available at all times. At 9 weeks before calving, the PL cows were dried off. Pregnant nonlactating (PNL) heifers (n = 8) formed the second group. Gestational length was 283.1 ± 2.2 days, and PNL heifers had an age at calving of 26.4 ± 0.5 months (mean ± SEM). The heifers were kept on pasture during summer and in a freestall barn during winter. They were fed according to their requirements for maintenance and growth with grass silage and hay. Minerals and water were freely available at all times. The cows and heifers were separated in a maternity pen when approaching parturition. All animals carried singleton pregnancies and were healthy throughout gestation.

2.2. Experimental design

Fetomaternal ECGs were recorded once weekly starting 14 weeks before the expected day of calving, calculated as 280 days after insemination. The last ECG recording was made 3.1 ± 0.6 days before calving in the PL cows and 2.6 ± 0.7 days before calving in the PNL heifers. Electrocardiography recordings were always obtained for 1 hour during the morning (between 8 AM and 12 PM), and during that time, the animals were fixed in feed fence headlocks with the possibility to ingest roughage. The experiment was approved by the Ethics and Animal Welfare Committee of the Vienna University of Veterinary Sciences (protocol number: 15/11/97/2010).

2.3. Electrocardiography

Fetomaternal ECG measurements were obtained with the Televet 100 recording system (Version 5.1.1.; Engel Engineering, Offenbach am Main, Germany) as described for horses [12] with modifications. Electrocardiography settings were 50 mm/s feed and 30 mm/mV gain. Maternal and fetal cardiac cycles were displayed and recorded in combined mode and separately from each other. The Televet 100 uses a filter enabling extraction of the fetal ECG signal from the abdominal ECG signal of the cow with additional amplification of the fetal signal for evaluation. The filter convergence was attuned to slow and 50 Hz.

The European standard colour scheme for diagnostic ECG systems was used for identification of electrodes. The electrodes were fixed after shaving on the skin of the cow with self-adhesive pads. The green electrode (left leg) was placed on the thorax one hand below the spine and behind the shoulder. The yellow electrode (left arm) was positioned at the left and the red electrode (right arm) at the right side of the abdomen at the height of the knee. The black electrode (neutral) was put on the cows left croup. The electrodes were connected to the Televet 100 recording device which was fixed to an elastic girth around the abdomen at the height of the flank of the cow. Data recorded were transmitted directly from the Televet 100 *via* Bluetooth to a laptop computer.