Theriogenology 86 (2016) 1498–1505

Contents lists available at ScienceDirect

Theriogenology

journal homepage: www.theriojournal.com

Stress response and cardiac activity of term and preterm calves in the perinatal period

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ARTICLE INFO

Article history:
Received 4 February 2016
Received in revised form 10 May 2016
Accepted 12 May 2016

Keywords:
Cattle
Fetus
Calf
Cortisol
Heart rate
Heart rate variability

ABSTRACT

This study tested the hypothesis of gestational age affecting fetal cardiac activity and the stress response at birth. Heart rate (HR), heart rate variability variables, SD of the beat-to-beat interval and root mean square of successive beat-to-beat differences, and postnatal salivary cortisol concentration were studied in calves born at term (Term, $n = 7$, gestation length 286.3 ± 2.1 days) or after induction of parturition (Preterm, $n = 7$, gestation length 279.6 ± 0.2 days). Observation periods covered the last month of gestation (phase A), the last hours before birth including the first stage of labor (phase B), and the neonatal period (phase C). Fetal HR decreased in phase A ($P < 0.001$) and did not differ between groups. During phase B, HR increased ($P < 0.05$) and was higher in Preterm than in Term calves in phases B ($P < 0.05$) and C ($P < 0.01$). In Term calves, heart rate variability increased from Day 6 until birth ($P < 0.05$). At birth, SD of the beat-to-beat interval was higher in Term than in Preterm calves ($P < 0.01$). On Day 1 after birth (phase C), HR accelerations were more frequent in Term than Preterm calves ($P < 0.01$), whereas decelerations were more frequent in Preterm calves ($P < 0.05$). Cortisol concentration increased postnatally ($P < 0.001$) and was correlated with gestation length ($r \geq 0.68$, $P < 0.01$). Because of a certain degree of immaturity, the ability to cope with the stress of birth may be impaired in calves born 1 week before term.

1. Introduction

The high and still growing rate of perinatal mortality in cattle [1] not only causes economic losses but also raises ethical and animal welfare concerns. Perinatal mortality is not only due to dystocia but occurs increasingly also after normal calving [1]. Therefore, a need for fetomaternal monitoring in late gestation and at calving is evident. Fetomaternal electrocardiograms (ECGs) have recently been introduced for fetal monitoring in cattle and with regard to prolonged recording times are advantageous to Doppler ultrasonography or cardiotocography at calving [2–6]. In horses, fetomaternal ECGs are used for fetal monitoring under field conditions [7], and in humans, fetal heart rate (HR) monitoring is a standard procedure [8].

As shown in different species (e.g., humans [9], horses [7], and cattle [2]), fetal cardiac activity depends on gestational age and, thus, on autonomous nervous system maturation. With ongoing gestation, the regulation of fetal cardiac activity by the sympathetic and parasympathetic nervous system becomes increasingly complex [9]. Whereas fetal HR has been determined at different stages of pregnancy and also directly at calving [2–6], only limited information is available on the immediate antenatal period.

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0093-691X/$ – see front matter © 2016 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.theriogenology.2016.05.008

Reducing birth weight of the calf by inducing parturition approximately 1 week before term has been shown to reduce maternal stress during labor [10]. To the best of our knowledge, correlations between neonatal birth weight or the duration of calving and the stress response in calves at birth have not been studied so far. Physiological stress parameters, such as the release of cortisol, catecholamines, and endorphins, have been studied in the immediate neonatal period in term and preterm calves delivered by different obstetrical procedures [11–13]. In these studies, however, observations started when the calves were born, and therefore, only the end point of the birth process was assessed and not always differentiated from the challenges of postnatal adaptation.

In calves, concentrations of glucocorticoids in plasma are high at birth and decrease rapidly within 6 hours after delivery [12]. Labor and delivery also stimulate the release of catecholamines, and highest epinephrine and norepinephrine concentrations were found in plasma of term calves before umbilical cord rupture [11]. By stimulating energy mobilization, thermogenesis, pulmonary surfactant release, respiration and cardiac function, catecholamines, and cortisol promote adaptation to the extrauterine environment after birth [11,12,14]. This initial stimulatory phase is followed by a pronounced release of enkephalins after umbilical cord rupture [11]. Enkephalins are co-stored with catecholamines in the adrenal medulla and have an inhibitory effect on catecholamine release. This suggests that norepinephrine-dominated stimulation during expulsion of the calf is followed by enkephalinergic inhibition after cord rupture and onset of respiration [11].

This study tested the hypothesis that gestational age affects the regulation of cardiac activity in the bovine fetus during the last month of gestation. We hypothesized that cardiac activity differs between calves born after induced parturition on Day 278 of gestation and calves born at term approximately 1 week later because of differences in fetal maturation. Furthermore, we tested whether calves born after induced parturition have a different stress response to the birth process itself and the challenges of postnatal adaptation than term calves born spontaneously. Therefore, fetal and neonatal HR and heart rate variability (HRV) were studied in late gestation, during birth, and postnatally. In addition, salivary cortisol concentration was determined postnatally in calves either born at term or after induced parturition 1 week before term.

2. Material and methods

2.1. Animals

The fetuses and newborn calves from 14 pluriparous Austrian dairy/dual-purpose Simmental cows with singleton pregnancies were included into this study. Age and parity of group Term and Preterm cows were 67.6 ± 9.2 and 67.0 ± 8.9 months and 3.3 ± 0.6 and 3.4 ± 0.6 gestations, respectively. Cows were housed in groups in a free-stall barn with straw-bedded cubicles at the Research and Teaching Farm of Vetmeduni Vienna and were dried-off 8 weeks before the expected day of calving. Average milk yield in the herd was 8900 kg per 305-day lactation. 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. Cows were separated in a straw-bedded maternity pen when approaching parturition and remained there until the end of the observation period 1 day after calving. All calves were born in anterior presentation, dorsoventral position, and extended posture. Calvings were observed, and duration of the second stage of labor (defined as time from rupture of the allantochorion until complete birth of the calf) was recorded. None of the calvings required veterinary intervention. Cows and their calves were clinically healthy throughout the study period, and the calves did not show clinical signs of prematurity, such as short hair, incisors covered by gingival, or reduced ability to stand or suckle. Calves were removed from their dams immediately after birth. They were fed high-quality colostrum within 2 hours after birth and, thereafter, three times during the first day of life.

2.2. Experimental design

The experiment was approved by the competent authority for animal experimentation in Austria (Federal Ministry for Science and Research, license number BMWF-68.205/0082-II/3 b/2013).

Cows were either allowed to calve spontaneously (group Term, $n = 7$; gestation length 286.3 ± 2.1 days) or calving was induced with the $PGF_{2\alpha}$ analog cloprostenol (0.5 mg intramuscularly, Estrumate; MSD Animal Health, Vienna, Austria) on Day 278 of gestation at 8 AM (group Preterm, $n = 7$). For distribution to groups, cows were ranked by date of last artificial insemination and allocated in alternating order to groups Term and Preterm [10]. Group Preterm calves were born after a gestation length of 279.6 ± 0.2 days (40.3 ± 3.2 hours after $PGF_{2\alpha}$ injection). Physiological gestation length of Preterm calves was assumed to be similar to Term calves, and thus, gestation length was 6.7 days shorter in group Preterm than in group Term ($P < 0.01$). From the fetal and newborn calves, cardiac beat-to-beat (RR) intervals were recorded at regular intervals throughout the last month of gestation, during the last hours before and first hours after birth, and on the first day of life. From the RR intervals, HR and time domain HRV variables SD of the beat-to-beat interval (SDRR) and root mean square of successive beat-to-beat differences (RMSSD) were calculated. For analysis of cortisol concentration, saliva samples were collected repeatedly during the first 2 hours after birth and three times during Day 1 of life.

The study period was subdivided into three phases. Phase A corresponded to the last 4 weeks of gestation before the onset of calving. Phase B started 20 hours before birth of the calf and, thus, included the first (defined as time from passive dilatation of the cervix to rupture of the allantochorion) and second stage of labor. Phase C included the neonatal period starting with birth of the calf.