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Parturition in horses is dominated by parasympathetic activity of the autonomous nervous system

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ABSTRACT

External and internal stressors prolong parturition in different species. At parturition, sympathoadrenal activation should be avoided because an increased sympathetic tone may cause uterine atonia via β_2 -receptors. We hypothesized that at physiological parturition, horses are under parasympathetic dominance, and stress-response mechanisms are not activated during delivery of the foal. To evaluate stress responses, heart rate, heart rate variability, catecholamines, and cortisol were analyzed in mares ($n = 17$) throughout foaling. Heart rate decreased from 2 hours before (51 ± 1 beats/minute) to 2 hours after delivery (41 ± 2 beats/minute; $P < 0.05$). Heart rate variability variables, standard deviation of the beat-to-beat interval, and root mean square of successive beat-to-beat differences, changed over time ($P < 0.05$) with the highest values within 15 minutes after delivery. The number of mares with atrioventricular blocks and the number of atrioventricular blocks per mare increased over time ($P < 0.01$) and were significantly elevated from 15 minutes before to 45 minutes after birth of the foal. Salivary cortisol concentrations increased to a maximum at 30 minutes after delivery (25.0 ± 3.4 ng/mL; $P < 0.01$). Plasma epinephrine and norepinephrine concentrations showed significant fluctuations from rupture of the allantochorion to expulsion of the fetal membranes ($P < 0.01$) but were not markedly elevated at any time. In conclusion, mares give birth under high parasympathetic tone. Cortisol release during and after foaling is most likely part of the endocrine pathways regulating parturition and not a labor-associated stress response.

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1. Introduction

The mechanisms for maintenance of pregnancy and the characteristics of parturition clearly differ between species. In horses, length of gestation is highly variable and, in contrast to ruminants and pigs, foaling takes place in the presence of still high progesterin concentrations [1]. Once initiated, equine parturition proceeds rapidly. The

expulsive phase of foaling should be completed after a maximum of 20 to 30 minutes and is often finished within half of that time [2]. Endocrine changes during labor thus occur within a very small time window and are difficult to differentiate. The regulation of labor in horses is, therefore, discussed at least in part controversially [3–5], and further studies are warranted.

Rapid expulsion of the foal requires powerful and coordinated myometrial and abdominal contractions. Stressors such as environmental disturbance prolong parturition and impair rapid delivery of the newborn in rats [6] and pigs [7]. In mares, parturition only takes place

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Table 1

Number of mares (n) from which data were obtained for different parameters from 120 minutes before to 120 minutes after delivery of the foal.

Time relative to end of second stage of labor (min)	-120	-90	-60	-30	-15	-5	+5	+15	+30	+60	+90	+120
Heart rate	9	10	10	11	11	11	11	11	11	11	11	11
AV blocks	9	10	10	11	11	11	11	11	11	11	11	11
HRV	7	8	8	9	9	—	—	9	9	9	9	9
Cortisol	—	—	—	—	—	—	17	17	17	17	17	17

Abbreviations: AV, atrioventricular; HRV, heart rate variability.

when the environment is perceived as safe. This is illustrated by the fact that in domestic horses, up to 90% of foals are born during the night, i.e., at a time of minimal disturbance in the stable [8].

Stress caused by labor has been mostly studied in women (reviewed by [9]). Pain or stress induces an immediate release of catecholamines from the adrenal medulla. In women, maternal sympathoadrenal activation during labor can be attenuated by adequate pain management [10]. Increased sympathoadrenal activity prepares the body for a “fight-or-flight” reaction. At the level of the myometrium, sympathetic activation of uterine β_2 -receptors causes myometrial relaxation as shown in humans and rats [11,12]. In humans, this is mimicked by the administration of β_2 -adrenergic stimulants to postpone parturition and treat preterm labor [11,12]. In cattle, the β_2 -adrenergic drug, clenbuterol is used to facilitate obstetrical manipulations [13]. Although such clinical use is uncommon in mares, clenbuterol decreases uterine tone at all stages of equine pregnancy [14]. Stress responses during parturition should be avoided because endogenous activation of β_2 -receptors may cause uterine atonia.

Increased sympathetic activity in response to acute stressors is not only reflected by catecholamine release but can also be evaluated by heart rate (HR) and heart rate variability (HRV) analysis. Heart rate variability, i.e., short-term fluctuations in HR, is based on the antagonistic oscillatory influences of the sympathetic and parasympathetic branch of the autonomic nervous system on the sinus node of the heart. Heart rate variability represents the fine tuning of the beat-to-beat (RR) control mechanisms and increases during dominance of the parasympathetic branch of the autonomous nervous system. In general, decreases in the HRV variables, standard deviation of RR interval (SDRR) and root mean square of successive RR differences (RMSSDs), reflect sympathetic dominance, whereas increased values indicate parasympathetic dominance [15].

Stressful stimuli increase cortisol release from the adrenal cortex. Non-protein-bound cortisol rapidly diffuses into saliva, and salivary cortisol mirrors changes of free cortisol in blood plasma [16]. Saliva can be collected easily and stress-free from horses of all ages

without the need to restrain the animal [1,17,18]. Increased cortisol release and decreased HRV indicate stress responses in horses [19,20].

Horses respond to potentially dangerous situations with an immediate flight reaction [21]. In domesticated horses, also anthropogenic challenges such as equestrian training [18,19], transport [20,22], or weaning of foals [17] increase cortisol release and HR and decrease HRV. On the other hand, the extremely rapid delivery of the foal requires the absence of sympathoadrenal activity and thus activation of β_2 -receptors at least during the expulsive phase of labor.

We hypothesized that at physiological parturition, horses are under parasympathetic dominance and stress-response mechanisms are not activated during delivery of the foal. To evaluate sympathoadrenal and adrenocortical activation at physiological, undisturbed foaling, we have analyzed HR and HRV, plasma catecholamines, and salivary cortisol concentration in parturient mares throughout delivery of their foals. For comparison, HR, HRV, and cortisol concentration were also studied in nonpregnant mares.

2. Material and methods

2.1. Animals

For this study, a total of 17 late-pregnant Warmblood brood mares (*Equus caballus*) with singleton pregnancies from the Brandenburg State Stud at Neustadt (Dosse), Germany, were available. Mares were between 4 and 15 years of age (7.1 ± 0.8 years). All mares and their foals were healthy throughout the study. Horses were fed oats and hay twice daily. Mineral supplements and water were freely available at all times. The horses were housed in group stables on straw with daily access to an outdoor paddock. Approximately 15 days before the calculated day of parturition, mares were separated into single boxes and were left in the foaling unit until 5 days after birth of their foal. In the foaling unit, mares were observed 24 hours per day from outside their box and without disturbing the animal. Average gestation length calculated from the day of ovulation was 337.5 ± 1.8 days. In all mares, parturition took place between 8:00 PM and

Table 2

Number of mares from which blood were collected at individual time points from rupture of the allantochorion until the end of second stage of labor and from birth of the foal until passage of the fetal membranes.

Time (min)	Rupture of allantochorion	+10	+20	Birth of foal	+10	+20	+30	+40	+50	+60	+70	+80	+90	-5.9 ± 0.7	Passage of fetal membranes
Mares (n)	10	5	1	10	9	6	4	3	1	1	1	1	1	10	10

The last two samples are aligned to the time of expulsion of the fetal membranes. Differing n numbers are due to differences in the duration of labor between mares.

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