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Hair cortisol concentrations in bovine neonates born to healthy and ill cows

U. Braun[1], F. Schubnell[1], U. Bleul[1], K. Nuss[1], M. R. Baumgartner[2], T. M. Binz[2]

[1]Department of Farm Animals, Vetsuisse Faculty, University of Zurich; [2]Centre for Forensic Hair Analytics, Zurich Institute of Forensic Medicine, University of Zurich

Haarcortisolkonzentrationen bei neugeborenen Kälbern von gesunden und kranken Kühen

Die Ziele der vorliegenden Arbeit waren es, zu untersuchen, ob sich die Haarcortisolkonzentrationen (HCC) von Kühen und ihren neugeborenen Kälbern unterscheiden und ob sich die HCC der Kälber von Müttern mit und ohne chronische Krankheiten unterscheiden. Die Untersuchungen wurden an 2 Gruppen mit insgesamt 40 Kühen und ihren 42 neugeborenen Kälbern durchgeführt. In der Gruppe 1 wurden die HCC von 19 gesunden Kühen und ihren neugeborenen Kälbern und in der Gruppe 2 diejenigen von 21 während der Trächtigkeit chronisch erkrankten Kühen und ihren neugeborenen Kälbern bestimmt. Dazu wurden bei allen Kühen und Kälbern am Tag der Kalbung Haarproben für die Cortisolbestimmung entnommen und mittels LC-MS/MS (Flüssigkeitschromatographie, gekoppelt mit Massenspektrometrie) untersucht.

In der Gruppe 1 war die durchschnittliche HCC der Kälber mit 31,0 pg/mg signifikant höher als diejenige der Kühe mit 0,6 pg/mg (P < 0,01). Ähnlich war dies in der Gruppe 2, in welcher die Kälber mit 19,4 pg/mg signifikant höhere HCC als die Kühe mit 0,8 pg/mg aufwiesen (P < 0,01). Während sich die HCC der Kühe der Gruppen 1 und 2 nur tendenziell unterschieden (0,6 vs. 0,8 pg/mg, P = 0,06), waren die HCC der Gruppe-1-Kälber mit 31,0 pg/mg signifikant höher als diejenigen der Gruppe-2-Kälber mit 19,4 pg/mg (P < 0,01). Die Ergebnisse lassen den Schluss zu, dass neugeborene Kälber um ein Vielfaches höhere HCC als ihre Mütter aufweisen und dass die HCC der Kälber von Müttern mit chronischen Krankheiten niedriger als diejenigen von gesunden Müttern sind. Inwieweit dies Auswirkungen auf das spätere Leben des Kalbes hat, muss durch weitere Untersuchungen erforscht werden.

Schlüsselwörter: Rind, Haarcortisolkonzentration, Vergleich Mutter – Kalb, Einfluss von Krankheiten

Summary

The goal of this study was to investigate the hair cortisol concentration (HCC) in healthy and ill cows and their newborn calves. A total of 40 cows and their 42 newborn calves were divided into two groups: group 1 consisted of 19 clinically healthy cows and their 20 newborn calves, and group 2 comprised 21 cows that had had a chronic illness in the third trimester of gestation and their 22 newborn calves. A liquid chromatography-tandem mass spectrometry (LC-MS/MS) system was used to measure the HCC in hair samples that were collected from the cows and calves on the day the calves were born.

In both groups, the mean HCCs of the calves was significantly higher than that of the cows (group 1, 31,0 vs. 0,6 pg/mg; group 2, 19,4 vs. 0,8 pg/mg; P<0,01). There was a trend for lower HCCs in cows of group 1 compared with cows of group 2 (0,6 vs. 0,8 pg/mg, P=0,06), whereas calves of group 1 had significantly higher HCCs than calves of group 2 (31,0 vs 19,4 pg/mg, (P<0,01). Based on our findings, newborn calves have much higher HCCs than their dams, and calves born to chronically ill cows have lower HCCs than calves born to healthy cows. More studies are needed to examine potential adverse long-term effects of chronic illness in the pregnant dam on the offspring.

Keywords: Cattle, hair cortisol concentration, cow-calf pair, effects of illnesses

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Introduction

Hair cortisol concentration (HCC) is considered a biomarker for chronic stress in cattle and has been investigated in numerous studies in healthy and ill cattle. [5,6,7,8,10,11,12,15,17,23] The most important aspects of using HCC in cattle were recently described (living, housing and management conditions; social behaviour, body condition and nutritional status; diseases and disorders and factors affecting hair cortisol concentrations such as age, sex, pregnancy, season of the year, hair colour, body region, stocking density, milk yield and phase of lactation).[16,29] Studies have shown that newborn calves have higher HCCs than 6-month-old calves[17] or mature cows.[9,15] Chronic illness[8,5,12] and stress, such as the stress associated with conversion from tie-stall to free-stall housing,[22] may also be associated with increased HCCs in cattle. Stress may occur prenatally and affect the HCC of newborn animals. Interestingly, two studies reported that the HCCs of infant monkeys[20] and newborn humans[25] born to mothers that underwent gestational stress were decreased rather than increased, which was unexpected. Infant rhesus monkeys had significantly lower HCCs after the mothers had been exposed to an acoustic startle protocol for at least 20 % of the gestation period compared with infants born to non-stressed mothers.[20] A possible explanation for this was an initial up-regulation in glucocorticoids in the fetal compartment during the period of maternal stress, which was then followed by a compensatory down-regulation of hypothalamic-pituitary-adrenal (HPA) axis activity. The authors were able to show that the blood cortisol concentrations were increased in the pregnant monkeys at the end of the acoustic disturbance, and they suggested that placental transfer of cortisol exerted an inhibitory effect on fetal HPA axis activity.[20] In a longitudinal study that involved 80 pregnant woman and their newborn infants, increased maternal HCCs in the first trimester caused by psychological stress, anxiety and depression were negatively associated with neonatal HCCs.[25] In another study, prenatal stress in the form of anxiety or depression in pregnant women was associated with a decrease in neonatal HCCs.[28] We hypothesize that chronic disease of the mother cow during pregnancy may affect maternal and foetal HPA axis activity and thus HCCs in both the mother and the neonate. Therefore, the objective of this study was to determine and compare the HCCs of healthy cows and cows with chronic disease during late gestation and the effects on the HCCs of their calves.

Materials and Methods

Overview

A total of 40 cows and their 42 newborn calves were divided into two groups. Cows of group 1 were clinically healthy throughout gestation and cows of group 2 had a chronic illness for at least three weeks during the last trimester of pregnancy. All calves were clinically healthy at birth. The calves of group 1 were born between March 2016 and June 2017 and those of group 2 between August 2016 and October 2017.

Group 1: 19 clinically healthy cows and their 20 newborn calves

The cows were recruited from a Swiss Braunvieh (n = 12) and a Swiss Fleckvieh herd (n = 7) and were a median of 6 years (range, 4 to 15 years) old. The cows were clinically healthy, had not received any medications in the last trimester of gestation and gave birth to 12 heifer and 8 bull calves (one set of twins). All calves had a normal birth and were clinically healthy.

Group 2: 21 cows with a chronic illness in the third trimester and their 22 newborn calves

The cows were from 21 herds. They had contracted a chronic illness in the last trimester (6,5 to 9,0 months pregnant, mean±sd=8,1±0,75 months) and were referred to the Veterinary Hospital of the University of Zurich. The duration of illness was at least three weeks. The group had a median age of 5 years (range, 2 to 9 years) and included Swiss Braunvieh (n = 14), Swiss Fleckvieh (n = 3), Holstein Friesian (n = 1) and crossbred cows (n = 3). The illnesses and treatments have been described in detail elsewhere.[26] In brief, 13 cows had complicated claw, joint and tendon sheath disorders, five had chronic peritonitis, one had a gluteal abscess, another had thymic lymphoma and one other had actinomycosis (Table 1). Some cows had more than one condition. Eight of the cows were euthanased or slaughtered because of the severity of the illness and were referred to as *non-surviving cows.* Euthanasia or slaughter occurred on the day of calving in five cows and on days 2, 3 and 14 postpartum in one cow each. Thirteen cows, hereafter referred to as *surviving cows*, were treated successfully and discharged.

Sixteen of the 21 cows received antibiotics (procaine penicillin, amoxicillin, oxytetracycline, gentamicin, cefquinome), 12 received a nonsteroidal anti-inflammatory drug (NSAID, ketoprofen), two received an antiparasitic (eprinomectin, triclabendazole, levamisole), four received a corticosteroid (dexamethasone) and 14 received more than one of these drugs. Dexamethasone at a daily dosage of 0,01 to 0,02 mg/kg was used in four cows (No. 12, 16, 17, 19) in the last four days before parturition with the sole purpose of induction of parturition. There were 11 heifer calves and 11 bull calves (one set of twins), and all had a normal birth and were clinically healthy.

Hair samples and determination of HCC

Hair samples were collected from the neck region of all cows and calves on the day of parturition as described previously.[6] The hair samples were dried and stored at room temperature wrapped in tin foil. Heavily soiled hair samples were brief-

ly washed in lukewarm water before storage. The HCC was measured at the Center for Forensic Hair Analytics, Zurich Institute of Forensic Medicine, University of Zurich, as described using a liquid chromatography-tandem mass spectrometry (LC-MS/MS) system.[3] The limit of detection (LOD) for cortisol was 0,10 pg/mg hair and the limit of quantification (LOQ) was 0,50 pg/mg hair. The HCCs from nine cows and three calves were between the LOD and the LOQ and were reported as 0,25 pg/mg. Four quality controls using 0,25 pg/mg were prepared and analysed in an attempt to use these 12 values quantitatively in the analysis. In all four, the signal-to-noise ratio was approximately 5, and thus quantification was feasible. The HCC of one cow that was below the LOD was reported as 0,00 pg/mg.

Statistical analysis

The program SPSS Version 26 (IBM SPSS Statistics 26,0, Switzerland) was used. The Shapiro-Wilk test was used to test the data for normality. Means ± standard deviations were calculated for normal data and medians for non-normal data. Differences in HCC between the cows and calves of groups 1 and 2 and between the cows and their calves were analysed using the Mann-Whitney U test. Differences in HCC between 13 surviving and 8 non-surviving cows of group 2 and between cows that had and had not received medical treatments (18 vs. 3 cows) of group 2 were analysed using ANOVA. Pearson's and Spearman's correlation coefficients were calculated for the correlations between HCCs of the cows and calves in group 1 and for the cows and calves in group 2. For normal data (group 1) Pearson's correlation coefficients and for non-normal data (group 2) Spearman's correlation coefficients were used. Differences were considered significant at P<0,05.

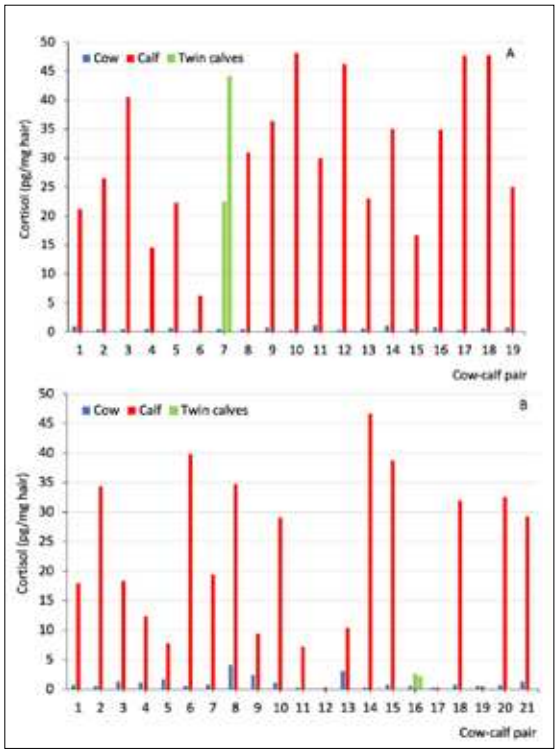

Figure 1: Frequency distribution of hair cortisol concentrations in clinically healthy cows and calves (group 1, A) and cows with a chronic illness in the third trimester and calves (group 2, B)

Ethics approval

The study was approved by the ethical committees of the canton of Zurich (permit 26058, ZH295/14), and all experiments were performed in accordance with relevant institutional, national, and international guidelines and regulations.

Results

Group 1 (19 Clinically healthy cows and their 20 newborn calves)

The HCCs of the cows ranged from 0,25 to 1,11 pg/mg and that of their calves from 6,26 to 48,10 pg/mg (Figure 1A). The mean HCC of the calves was 31,0 pg/mg, which was 52 times the mean HCC of the cows (0,6 pg/mg, P<0,01) (Table 2). There was no significant correlation between the HCCs of the cows and the calves (r=-0,14, Pearson's correlation coefficient).

Group 2 (21 Cows with a chronic illness in the third trimester and their 22 newborn calves)

The HCCs ranged from 0,00 to 4,05 pg/mg in the cows and from 0,25 to 46,70 pg/mg in their calves (Figure 1B). The mean HCC of the calves was 19,4 pg/mg, which was 24 times the median HCC of the cows (0,8 pg/mg, P<0,01) (Table 2). There was no significant correlation between the HCCs of the cows and the calves (r=0,18, Spearman's correlation coefficient).

The median HCCs of the 13 surviving and the eight non-surviving cows did not differ significantly (0,8 vs. 0,7 pg/mg hair) (Table 2). By contrast, the mean HCC of the 14 calves of the surviving cows was 3,8 times that of the eight calves of the non-surviving cows (26,5 vs. 6,9 pg/mg; P<0,01).

The HCC of the 18 cows that had been treated with antibiotics, NSAIDs, dexamethasone, antiparasitics or with a combination of these drugs did not differ significantly from the concentration of the 3 untreated cows. The same was true for the calves of these cows with the exception of the 5 calves (Nos. 12, 16A, 16B, 17, 19, Figure 1B) born to cows that had been induced with dexamethasone (cows belonging to the 18 treated cows); these calves had significantly lower median and mean HCCs than the calves born to cows that had not received dexamethasone (median, 0,49 vs. 29,1 pg/mg; mean, 1,1 vs. 24,7 pg/mg; both P<0,05).

Comparison of groups 1 and 2

The mean HCC of the healthy cows tended to be lower than that of the cows with a chronic illness in the last trimester (0,6 vs. 0,8 pg/mg, P=0,06, Table 2). In contrast, the mean HCC of the calves of group1 was 1,6 times that of the calves of group 2 (31,0 vs. 19,4 pg/mg, P<0,01). When the HCC of the 5 calves born to dexamethasone-treated cows are excluded from the calculation, groups 1 and 2 do not differ significantly (31,0 vs. 24,7 pg/mg, P>0,05).

Discussion

The principal finding of the present study was that newborn calves have significantly higher HCCs than their dams, which was in agreement with earlier reports that newborn calves have much higher HCCs than six-month-old calves[9,17] and cows.[9] Those two studies compared cows and calves that were not related, whereas the present novel investigation evaluated the HCCs of cow-calf pairs. Analogous to our findings, calves had higher blood cortisol concentrations than their dams, but in contrast to the HCCs in the cow-calf pairs, the blood cortisol concentrations of cows and their calves were significantly correlated.[27] The HCCs of human mothers and their newborn infants were weakly but significantly correlated.[19]

The hair samples were collected on the day the calves were born and therefore the HCCs reflected prenatal homeostatic regulation of the hormone. In most mammals, the fetal plasma glucocorticoid concentration increases 10 to 15 days before birth[14] inducing maturational changes in various organs

Table 1: Breed, age, gestation length, disease, outcome and hair cortisol concentrations in cows with a chronic illness in the third trimester, and their calves (cow-calf pairs, group 2).

No.	Breed, age (gestation length)	Disease	Outcome	HCC Cow	HCC Calf
1	CC, 5 yrs, (9 mos)	Ehrlichiosis, severe black fly (Simuliidae) infestation, gastrointestinal parasitism, sole ulcer	D	0,7	17,96
2	BS, 3 yrs, (9 mos)	Purulent infection of 12-cm wound of the left metatarsus with exposure of bones, left tarsal swelling	D	0,6	34,36
3	HF, 5 yrs, (8 mos)	Left displaced abomasum, 20×20 cm gluteal abscess on left side	D	1,3	18,37
4	BS, 2 yrs, (8 mos)	Chronic infection of a proximal interphalangeal joint, tendovaginitis of a common digital flexor tendon	D	1,1	12,39
5	SF, 5 yrs, (8 mos)	Traumatic reticuloperitonitis, downer cow syndrome	S	1,7	7,72
6	BS, 5 yrs, (6.5 mos)	Traumatic reticuloperitonitis, fascioliasis	D	0,6	39,78
7	BS, 3 yrs, (8 mos)	Complicated claw lesion with septic arthritis of the proximal and distal interphalangeal joints, fibrinous tendovaginitis, phlegmon	E	0,8	19,42
8	BS, 4 yrs, (8 mos)	Purulent generalised and localised peritonitis	D	4,1	34,72
9	CC, 7 yrs, (9 mos	Traumatic reticuloperitonitis, pericarditis, fascioliasis	S	2,4	9,41
10	BS, 6 yrs, (8 mos)	Purulent toe tip necrosis in both hind feet	D	1,1	29,08
11	BS, 5 yrs, (9 mos)	Thymic lymphoma	S	0,25	7,20
12	BS, 9 yrs, (8.5 mos)	Fibrinous gonitis	E	0,0	0,25
13	BS, 7 yrs, (9 mos)	White line disease with double sole and bone involvement	S	3,1	10,39
14	CC, 5 yrs, (7 mos)	Localised peritonitis with abscess	D	0,25	46,70
15	SF, 4 yrs, (7 mos)	Complicated white line disease, tendovaginitis of digital flexor tendon	D	0,8	38,77
16	BS, 3 yrs, (8.5 mos)	Septic tendovaginitis of common digital flexor tendon	D	0,6	twin1: 2,59 twin2: 2,10
17	BS, 3 yrs, (8.5 mos)	Septic arthritis of the proximal interphalangeal joint	E	0,25	0,25
18	BS, 2 yrs, (8.5 mos)	Actinomycosis	D	0,8	31,95
19	BS, 5 yrs, (8 mos)	Complicated sole ulcer and osteomyelitis of the third phalanx and distal sesamoid bone, distal interphalangeal arthritis	E	0,6	0,49
20	SF, 5 yrs, (7 mos)	Interdigital hyperplasia in a hind food and sole ulcer	D	0,7	32,55
21	BS, 3 yrs, (8 mos)	Complicated white line disease and distal interphalangeal arthritis	D	1,3	29,30

Breed: BS Brown Swiss; HF Holstein Friesian; SF Swiss Fleckvieh, CC Crossbred cow
Age/gestation length: yrs (age in years), mos (gestation length in months)
Outcome: D Discharged, E Euthanasia, S Slaughter

as well as initiating the cascade of events that leads to the onset of parturition.[30] The plasma cortisol concentration of Jersey calves increased from less than 5 ng/ml on day 250 of gestation to 10 ng/ml one week before birth to a mean concentration of 61 ng/ml one hour before birth.[13] This could explain, at least in part, the significantly higher HCCs of the calves of the present study compared with their dams. Another possibility is that the high HCCs of the calves resulted from a transfer of cortisol from the dam to the fetus; cows in advanced pregnancy have significantly higher serum cortisol concentrations than cows in early pregnancy,[1] and fresh cows have higher HCCs than non-lactating open cows.[9] Newborn humans also have much higher HCCs than their mothers.[18,19] Several theories have been proposed to explain these differences including differences in hair growth and hair structure between mother and infant,[19] an effect of cortisol in fetal fluids[18,19,20] and an effect of placental corticotropin-releasing hormone on cortisol synthesis in the fetal adrenal glands.[19] More research is needed to clarify how and at what stage of gestation cortisol is deposited in fetal hair, and whether the cortisol detected in the hair of neonatal calves is of fetal or maternal origin or a combination of the two.

The finding that calves born to healthy cows had significantly higher HCCs than calves born to chronically ill cows was in agreement with observations in humans[25,28] and rhesus monkeys.[20] Those studies showed that stress in the pregnant mother results in a decrease in HCC in the infant. It is conceivable that chronically ill cows may have elevated blood cortisol concentrations that can cross the placental barrier, reducing fetal cortisol synthesis in the adrenal glands via negative feedback. This notion is supported by the findings of a study in which pregnant ewes received dexamethasone or a placebo at days 104 to 106 of gestation; fetuses from ewes treated with dexamethasone had lower plasma cortisol concentrations than fetuses from controls.[21] Fetuses of ewes that had received four dexamethasone treatments on days 40 and 41 of gestation had lower plasma cortisol concentrations on day 50 of gestation than fetuses from control ewes.[4] The researchers assumed that this was due to suppression of the fetal HPA axis leading to a decrease in cortisol synthesis and release. An earlier study in sheep reported that at least 60 % of the fetal plasma cortisol was produced by the fetal adrenal glands.[2]

The HCCs of two twin pairs were of particular interest. The HCCs of twin calves born to a healthy cow (no. 7) were dissimilar (22,5 and 44,1 pg/mg), whereas those of twins born to a chronically ill cow (no. 16) were similar (2,59 and 2,10 pg/mg) (Figure 1). The heritability for HCC in human twins was calculated to be 0,72,[24] emphasizing the importance of genetic factors as a determinant for HCC. We suspect that the low HCCs of the calves born to the cows induced with dexamethasone were not attributable to this treatment but rather to the chronic illness of their dams. The time period between treatment and hair collection (1 to 4 days) was not long enough to have had an effect on HCC. This is supported by the findings from another study, in which treatment with dexamethasone (0,017 mg/kg) in eight cows with ketosis did not affect the HCCs of samples collected six and nine days later.[31] However, the difference between the two groups of calves was not significant when the 5 calves born to dexamethasone-treated cows were excluded from the calculation. This finding suggests that dexamethasone treatment of the dam may affect HCC in neonates, which warrants further research.

Table 2: Hair cortisol concentration of cows and calves by group and survival of dam (mean ± standard deviation, median, minimum to maximum).

Comparison	Classification	Hair cortisol concentration (pg/mg)	
		Cows	Calves
Group 1 vs group 2	Group 1 (healthy)	0,6 ± 0,26 (0,25–1,11) (n=19)	31,0 ± 12,27[a,b] (6,26–48,10) (n=20)
	Group 2 (diseased)	0,8 (0,00–4,05) (n=21	19,4 ± 14,97[c] (0,25–46,70) (n=22)[1]
Surviving/ non-surviving cows	Surviving cows (group 2)	0,8 (0,25–4,05) (n=13)	26,5 ± 13,73[d] (2,10–46,70) (n=14)
	Non-surviving cows (group 2)	0,7 (0,00–3,12) (n=8)	6,9 ± 6,61 (0,25–19,42) (n=8)

[a] Different from healthy cows (P<0,01)
[b] Different from calves of diseased cows (P<0,01)
[c] Different from diseased cows (P<0,01)
[d] Different from calves of non-surviving cows (P < 0,01)

[1] Without the 5 calves born to dexamethasone-treated cows, the HCC of group 2 is 24,7 ± 12,64 pg/mg and does not differ significantly from the HCC of group 1.

Conclusions

We concluded that newborn calves born to healthy cows have HCCs many times higher than those of their dams, and that calves born to chronically ill cows tend to have lower HCCs than calves born to healthy cows. More studies are needed to examine potential adverse long-term effects of chronic illness in the pregnant dam on the offspring.

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Concentrations de cortisol dans les poils de vaches saines et malades et de leurs nouveau-nés

Le but de cette étude était d'étudier la concentration de cortisol dans les poils (HCC) chez des vaches saines et malades et chez leurs veaux nouveau-nés. Un total de 40 vaches et leurs 42 veaux nouveau-nés ont été divisés en deux groupes: le groupe 1 comprenait 19 vaches cliniquement saines et leurs 20 veaux nouveau-nés, et le groupe 2 comprenait 21 vaches ayant eu une maladie chronique au cours du troisième trimestre de gestation et leurs 22 veaux nouveau-nés. Un système de chromatographie liquide avec spectrométrie de masse en tandem (LC-MS/MS) a été utilisé pour mesurer le HCC dans des échantillons de poils prélevés sur les vaches et les veaux le jour de leur naissance.

Dans les deux groupes, le HCC moyen des veaux était significativement plus élevé que celui des vaches (groupe 1, 31,0 pg/mg contre 0,6 pg/mg ; groupe 2, 19,4 pg/mg contre 0,8 pg/mg ; P<0,01). Il y avait une tendance à des HCC plus faibles chez les vaches du groupe 1 par rapport aux vaches du groupe 2 (0,6 pg/mg vs. 0,8 pg/mg, P=0,06), alors que les veaux du groupe 1 avaient des HCC significativement plus élevés que les veaux du groupe 2 (31,0 pg/mg vs. 19,4 pg/mg, (P<0,01). Sur la base de nos résultats, les veaux nouveau-nés ont des HCC beaucoup plus élevés que leurs mères et les veaux nés de vaches chroniquement malades ont des HCC plus faibles que les veaux nés de vaches saines. D'autres études sont nécessaires pour examiner les effets négatifs potentiels à long terme d'une maladie chronique chez la femelle gestante sur la progéniture.

Mots clés: Bovins, concentration de cortisol dans les poils, paire vache-veau, effets des maladies

Concentrazione di cortisolo nei peli dei vitelli appena nati da bovine sane o malate

L'obiettivo di questo studio era di analizzare la concentrazione di cortisolo nei peli (HCC) in un gruppo di mucche sane e malate e dei loro vitelli appena nati. Un totale di 40 mucche e dei loro 42 vitelli appena nati è stato suddiviso in due gruppi: il gruppo 1 era composto da 19 mucche clinicamente sane e dai loro 20 vitelli neonati, mentre il gruppo 2 comprendeva 21 mucche che avevano avuto una malattia cronica nel terzo trimestre di gestazione e i loro 22 vitelli neonati. È stato utilizzato un sistema di cromatografia liquida e spettrometria di massa in tandem (LC-MS/MS) per misurare l'HCC nei campioni di pelo prelevati dalle mucche e dai vitelli il giorno della loro nascita.

In entrambi i gruppi, l'HCC media nei vitelli era significativamente più alta di quella delle mucche (gruppo 1, 31,0 vs. 0,6 pg/mg; gruppo 2, 19,4 vs. 0,8 pg/mg; P<0,01). Si è riscontrata una tendenza per un'HCC più bassa nelle mucche del gruppo 1 rispetto a quelle del gruppo 2 (0,6 vs. 0,8 pg/mg, P=0,06), mentre i vitelli del gruppo 1 avevano un'HCC significativamente più alta rispetto ai vitelli del gruppo 2 (31,0 vs. 19,4 pg/mg, (P<0,01). In base ai nostri risultati, i vitelli appena nati hanno un'HCC molto più elevata rispetto alle loro madri e per quanto riguarda i vitelli nati da mucche cronicamente malate, essi hanno un'HCC più bassa rispetto ai vitelli nati da mucche sane. Ulteriori studi sono necessari per esaminare i potenziali effetti negativi a lungo termine della malattia cronica della madre gravida sulla prole.

Parole chiave: Bovini, concentrazione di cortisolo nel pelo, coppia mucca-vitello, effetti della malattia

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Korrespondenzadresse

Ueli Braun
Departement für Nutztiere, Vetsuisse-Fakultät,
Universität Zürich
Winterthurerstrasse 260
CH-8057 Zürich
Telefon: +41 52 7 41 50 60
E-Mail: ueli.braun@uzh.ch