Hair cortisol concentration in clinically healthy slaughter calves with and without chronic bronchopneumonic lesions*

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Summary

The hypothesis of this study was that healthy calves undergo less stress and thus have lower hair cortisol concentrations than calves with chronic bronchopneumonic lesions. Fifty healthy calves (group 1) and 50 calves with chronic bronchopneumonic lesions (group 2) were used immediately after slaughter, at which time hair samples and both adrenal glands were collected. The hair samples and the left adrenal gland were used for cortisol measurement and the right adrenal gland was used for histological and morphometrical examinations. The median hair cortisol concentrations of calves in groups 1 and 2 were 1.6 and 1.9 pg/mg hair, respectively, and did not differ significantly. The same was true for the mean cortisol concentration of the adrenal gland (1.1 and 1.4 µg/g tissue) and for the adrenal cortisol content (3.7 and 4.6 µg). The weights of the cortex (3.3, mean, and 3.5 g, median) and medulla (1.7 and 1.8 g, both median) did not differ significantly between the groups. This study did not detect differences in hair and adrenal cortisol concentrations between clinically healthy slaughter calves with and without chronic bronchopneumonic lesions. In further studies, calves with clinical signs should be taken into account.

Keywords: calf, lung, bronchopneumonia, cortisol, hair, adrenal gland

Haarcortisolkonzentrationen bei klinisch gesunden Schlachtkälbern mit und ohne bronchopneumonische Läsionen

Die Hypothese der vorliegenden Arbeit bestand darin, dass Kälber ohne bronchopneumonische Lungenveränderungen weniger endogenem Stress ausgesetzt sind als solche mit veränderten Lungen und dass sich dies in unterschiedlichen Haarcortisolkonzentrationen manifestiert. Die Untersuchungen wurden an je 50 Schlachtkälbern ohne und mit bronchopneumonischen Lungenveränderungen unmittelbar nach deren Schlachtung durchgeführt. Von allen Kälbern wurden Haarproben und beide Nebennieren entnommen. Die Haarproben und die linken Nebennieren wurden für die Cortisolbestimmung und die rechten Nebennieren für die histologische und morphometrische Untersuchung verwendet. Die durchschnittlichen Haarcortisolkonzentrationen der Kälber ohne und mit Bronchopneumonie (Medianwerte) betrugen 1.6 und 1.9 pg/mg Haar und unterschieden sich nicht signifikant. Das Gleiche galt für die durchschnittlichen Cortisolkonzentrationen pro Gramm Nebennierenrinde der beiden Gruppen mit 1.1 und 1.4 µg/g sowie für die Gesamcortisolgehalte der Nebennierenrinde mit 3.7 und 4.6 µg (Medianwerte). Auch die Gewichte der Nebennierenrinde (3.3, Mittelwert, vs. 3.5 g (Medianwert) und des Nebennierenmarks (1.7 vs. 1.8 g, Medianwerte) der beiden Tiergruppen unterschieden sich nicht signifikant. Mit der vorliegenden Untersuchung liessen sich in Bezug auf die Haar- und Nebennierenrinden-Cortisolkonzentrationen keine Unterschiede zwischen den Kälbern ohne und mit bronchopneumonischen Lungenveränderungen nachweisen. In einer zukünftigen Untersuchung sollen Kälber mit klinischen Symptomen einer Bronchopneumonie untersucht werden.

Schlüsselwörter: Kalb, Lunge, Bronchopneumonie, Cortisol Haare und Nebennieren

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* Dedicated to Professor Adrian Steiner on the occasion of his 60th birthday in appreciation of his outstanding and dedicated collaboration with the veterinary community

Introduction

During hair growth, cortisol diffuses passively into the hair shaft[24] where it is stored.[32] Hair cortisol concentration is considered a novel biomarker for chronic stress in humans,[22,25] and it has been shown that chronic stress caused by severe chronic pain results in an increase in hair cortisol concentration.[30] There have been several studies on hair cortisol concentration in healthy[5,7,10,14,23] and ill cows.[4,8,12] Ill cows had higher hair cortisol concentrations than healthy cows[8,12] and chronically ill cows had higher concentrations than acutely ill cows.[4] It was therefore concluded that hair cortisol concentration is significantly correlated with the health status of cows.[8,12] However, not all diseases affect the health status or result in an increase in hair cortisol concentration. Cows with subclinical endometritis had the same hair cortisol concentrations as healthy cows,[4,8] whereas cows with mastitis or metritis had higher concentrations than healthy cows.[12] Chronically lame cows[4] and cows with multiple illnesses[12] had the highest hair cortisol concentrations.

The majority of published reports on hair cortisol have dealt with adult cattle, and there are few studies in calves.[14,20,21] Fifteen-day-old healthy calves had higher hair cortisol concentrations than 2-year-old cows,[14] analogous to the observation in humans that children have higher hair cortisol concentrations than adults.[3] A study on the effect of rest stops during long-distance transport of beef calves found that calves that were transported in a trailer for 15 hours, then unloaded, rested, fed and watered for 15 hours before being transported for another five hours had lower hair cortisol concentrations 25 days later than calves that remained in the trailers during the rest period without food and water.[20] Band-castrated, one-week-old calves that did not receive pain medication had higher hair cortisol concentrations 56 days later compared with calves that underwent the same procedure and received one dose of subcutaneous meloxicam.[21] In contrast, veal calves raised under a husbandry system that fulfilled minimal welfare requirements had the same hair cortisol concentration as calves raised under more stringent welfare conditions.[31] To our knowledge, the effect of bronchopneumonia on hair cortisol concentration of calves has not been investigated even though bronchopneumonia is one of the most common diseases of veal calves.[2] Bronchopneumonia adversely affects the health status, growth and survival of calves and results in increased age at first calving.[27] Cows that suffered from bronchopneumonia as calves had lower first-lactation milk production and a higher risk of leaving the herd during first lactation than cows without bronchopneumonia in calfhood.[1] Enzootic bronchopneumonia is a multifactorial disease caused by bacteria and viruses and exacerbated by unfavourable environmental conditions and various host risk factors.[13] Stress and associated reduced immunity allow the pathogens to emerge.[16] Chronic disease constitutes a severe endogenous stress leading to cortisol-induced immune suppression and in turn further reduction in condition and increased susceptibility to infection.[32] This led to our hypothesis that calves with chronic bronchopneumonic lesions have higher hair cortisol concentrations than healthy calves and that increased cortisol concentrations of affected calves are responsible for immune suppression and subsequent further deterioration in health status. A secondary hypothesis was that adrenal gland weight, size and cortisol content differ between healthy calves and calves with chronic bronchopneumonic lesions.

Materials and methods

Study design

The study involved 100 veal calves that were slaughtered from September 2016 to April 2017 at the Zurich slaughter facility. Fifty calves were healthy (group 1) and 50 had chronic bronchopneumonic changes (group 2). Hair samples and both adrenal glands were collected from all calves immediately after slaughter; hair samples and the left adrenal gland were used for cortisol measurement and the right adrenal gland was used for histological and morphometric examinations. The abomasum of all calves was examined and only calves without ulcers were used for the study to exclude possible effects of ulcers on the examined variables.

Calves

Group 1 included 50 calves that were 156 ± 19 (mean ± sd) days old, had a live weight of 136 ± 15 kg and normal lungs. To be included in group 1, it was necessary for calves to be clinically healthy and free of signs of bronchopneumonia, joint disease, omphalitis and abomasal lesions at carcass inspection. Group 2 comprised 50 calves that were 159 ± 29 days old, had a live weight of 133 ± 16 kg and had chronic bronchopneumonic lesions. To be included in group 2, it was necessary for calves to have chronic bronchopneumonic lesions that involved at least one third of the entire lung. The remaining inclusion criteria were the same as for group 1.

Slaughter and procurement of hair and organ samples

Three individuals from the Ruminant Clinic were involved in the procurement of hair samples, the assessment of the internal organs (together with the meat inspector) and the removal of the abomasum at the time of slaughter. Individual 1 was positioned at the kill floor,

and immediately after stunning and exsanguination collected approximately 3 g of pigmented hair from the forehead of each calf using electric clippers. The hair samples were placed in a plastic container and stored and analysed as described.[4] Individual 2 was positioned at the evisceration line and together with the meat inspector examined the lungs macroscopically and by palpation for abnormalities. The trachea and major bronchi were cut lengthwise and the pulmonary lymph nodes were incised. Calves with completely normal lungs were assigned to group 1 and calves with bronchopneumonic lesions involving at least one third of the entire lung were assigned to group 2. Individual 2 also collected both adrenal glands, which were stored in plastic bags and transported to the laboratory for analysis within 4 hours of collection. Individual 3, also positioned at the evisceration line, separated the abomasum from the gastrointestinal tract and stored it in a plastic bag. At the clinic, each abomasum was opened along the greater curvature and the mucosa rinsed with water to allow macroscopic evaluation for possible ulcers. Only calves without ulcers and lesions in other organs were included in the study. It was necessary to examine a total of 118 calves to have enough calves for both groups.

Hair cortisol measurement

The hair cortisol concentration was measured by means of liquid chromatography tandem mass spectrometry (LC-MS/MS) as described.[3] The same technique has been used to measure cortisol concentration in hair of adult cattle.[4,5]

Cortisol extraction and measurement in the cortex of the left adrenal gland

Adherent tissues were removed from the left adrenal gland of all calves using scissors, and the glands were weighed. Cortisol extraction from the cortex and cortisol measurement were done as described[6]. In brief, the left adrenal gland was cut in half sagittally using a scalpel blade, and the cortex and medulla of each half were separated and weighed. Cortisol extraction was done according to a published protocol[17] and the extraction protocol of the Cortisol EIA Kit (Oxford Biomedical Research, Product Number EA65). The cortisol concentration of the extract was measured via the Immulite cortisol test (Siemens Healthcare Diagnostics GmbH, Zurich, Switzerland), which used a fully automated chemiluminescent technique (Immulite® 1000, Siemens Healthcare Diagnostics GmbH, Zurich, Switzerland). The results of a spiking assay to determine the accuracy and the precision of the cortisol assay and a within-assay precision test were previously described.[6]

Histological examination of the right adrenal gland

After preparation, the adrenal glands were weighed, fixed in 4% formalin, processed routinely and examined histologically as described.[6,31] Tissue sections were made from cross-sectional 20 × 15 × 5-mm pieces of fixed adrenal gland that included both cortex and medulla and stained with haematoxylin and eosin (H&E). Digital scans (Hamamatsu NanoZoomer) made from H&E-stained sections were assessed morphometrically using the program NDP.view2 NanoZoomer Digital Pathology (Hamamatsu). The thickness of the adrenal capsule, zona glomerulosa, zona fasciculata and zona reticularis and the size of the adrenal medulla were determined. The zona fasciculata and zona reticularis were analysed as a single layer because they are difficult to differentiate in H&E-stained sections. The capsule and the layers of the cortex were measured at 10 different locations and the medulla at 5 different locations. Mean values as well as the corticomedullary ratio were calculated.[29]

Statistical analysis

The programs R (R Core Team, R Foundation for Statistical Computing, Vienna) and STATA 12.1 (StataCorp LP, College Station, Texas, USA) were used to analyse the following variables: age, body weight, cortisol concentrations of hair and extracts of the left adrenal gland, absolute and relative (in relation to body weight) weights of both adrenal glands and size of adrenal structures (capsule, cortex, medulla). The Wilk-Shapiro test was used to test numerical variables for normality. Means and standard deviations were calculated for normal variables and the median with 25% and 75% quartiles were calculated for non-normal variables. Non-normal data were log-transformed to generate log-normal distributions. The relationship among numerical data was examined using analysis of variance (ANOVA), and the relationship among ordinal data was analysed using the Kruskal-Wallis test. Pearson's correlation coefficients were calculated. Statistical power was calculated for each variable using the sampling procedure of the STATA program. Differences were considered significant at $P < 0.05$.

Results

Hair cortisol concentration

The median hair cortisol concentrations of calves of groups 1 and 2 were 1.6 [25 to 75% quartiles = 1.3 to 2.8 pg/mg] and 1.9 [1.5 to 2.5] pg/mg hair, respectively. The median concentrations and frequency distributions did not differ between groups (Table 1, Fig. 1). The majority (97%) of all cortisol concentrations ranged from 0.1 to 5.0 pg/mg hair, and the maximum concentration was 7.3 pg/mg hair.

Absolute and relative adrenal weights

The absolute weights of the left and right adrenal glands did not differ significantly between groups (left, 5.2 ± 1.0 vs. 5.3 [4.6 – 6.1] g; right, both 5.0 g, medians) (Table 1). The same was true for the relative adrenal weights (data not shown). Additionally, the weights of the cortex (3.3 ± 0.7 vs. 3.5 [2.8 – 4.1] g, and medulla (1.7 [1.5 – 2.2] vs. 1.8 [1.6 – 2.0] g) of the left adrenal gland did not differ significantly between groups 1 and 2.

Cortisol concentration of the left adrenal gland

The cortisol concentrations of calves of groups 1 and 2 were 1.1 [0.8 – 2.3] and 1.4 [0.9 – 2.4] µg/g (medians), respectively. The mean concentrations and the frequency distributions did not differ significantly (Table 1, Fig. 2). The majority (98%) of all cortisol concentrations ranged from 0.5 to 5.0 µg/g adrenal cortex and the maximum concentration was 5.5 µg/g.

The total amounts of adrenal cortisol were 3.7 [2.3 – 7.4] (group 1) and 4.6 [3.0 – 8.7] µg (group 2) and did not differ significantly (Table 1, Fig. 3). The majority (90%) of all amounts ranged from 2.1 to 12 µg, and the maximum amount was 28.8 µg.

Morphometrical and histological findings of the right adrenal gland

The combined thickness of the zona fasciculata and zona reticularis was significantly greater in group 1 than in group 2 (1479 ± 249 vs. 1425 [1278 - 1657] µm, $P < 0.05$) (Table 1). Likewise, the medulla of calves of group 1 was thicker than the medulla of calves of group 2 (3305 [2894 to 3741] vs. 3178 [2759 to 3705] µm, $P < 0.01$). In contrast, the capsule was thicker in group 2 than in group 1 (145 ± 27 vs. 132 ± 22 µm, $P < 0.01$). The other variables (total cortical thickness, thickness of zona glomerulosa, corticomedullary ratio) did not differ between groups. Twenty-four calves had nodular hyperplasia, 12 had melanosis and 5 calves had both of these lesions.

Correlations

There was no significant correlation between cortisol concentrations of hair and adrenal cortex for both groups combined ($r = -0.09$). Likewise, there were no significant correlations between hair cortisol concentration and absolute adrenal weight (left, $r = 0.07$; right, $r = 0.10$) and between hair cortisol concentration and relative adrenal weight (left, $r = 0.12$; right, $r = 0.15$).

Analysis of the statistical power

Depending on the variability in the different variables, the statistical power varied widely at the level of significance of 0.05 and ranged from 0.05 to 1.00. The variables adrenal cortisol content and weight of medulla had values of 0.95 and 1.00, respectively, and thus exceeded the standard of adequacy of 0.80.

Discussion

The hypothesis that hair cortisol concentrations of healthy slaughter calves and calves with chronic bronchopneumonic lesions differ was rejected based on the results of this study even though calves of the latter

Table 1: Results of cortisol measurements in hair and adrenal glands and morphometric examinations of adrenal glands in 50 healthy slaughter calves and 50 calves with chronic bronchopneumonic lesions (mean ± standard deviation or median [25 and 75% quartiles])

		Group		
Organ/Substrate	Variable	1 (Healthy)	2 (Chronic bronchopneumonic lesions)	Statistical power
Hair	Cortisol (pg/mg hair)	1.6 [1.3 – 2.8]	1.9 [1.5 – 2.5]	0.25
Left adrenal gland	Total weight (g)	5.2 ± 1.0	5.3 [4.6 – 6.1]	0.20
	Weight of cortex (g)	3.3 ± 0.7	3.5 [2.8 – 4.1]	0.05
	Weight of medulla (g)	1.7 [1.5 – 2.2]	1.8 [1.6 – 2.0]	1.00
	Cortisol concentration (µg/g tissue)	1.1 [0.8 – 2.3]	1.4 [0.9 – 2.4]	0.23
	Adrenal cortisol content (µg/ adrenal cortex)	3.7 [2.3 – 7.4]	4.6 [3.0 – 8.7]	0.95
Right adrenal gland	Total weight (g)	5.0 ± 0.9	5.0 [4.4 – 5.6]	0.14
	Thickness of cortex (µm)	1808 ± 268	1840 ± 342	0.07
	Thickness of medulla (µm)	3305 [2894 – 3741]	3178 [2759 – 3705]**	0.12
	Corticomedullary ratio	0.5 ± 0.2	0.6 [0.5 – 0.7]	0.15
	Thickness of capsule (µm)	132 ± 22	145 ± 27**	0.72
	Thickness of zona glomerulosa (µm)	329 ± 57	316 [278 – 353]	0.16
	Combined thickness of zona fasciculata and zona reticularis (µm)	1479 ± 249	1425 [1278 – 1657]*	0.09
	Prevalence of nodular hyperplasia	20/50	4/50	
	Prevalence of melanosis	7/50	5/50	

*/** Groups differ ($P < 0.05, 0.01$)

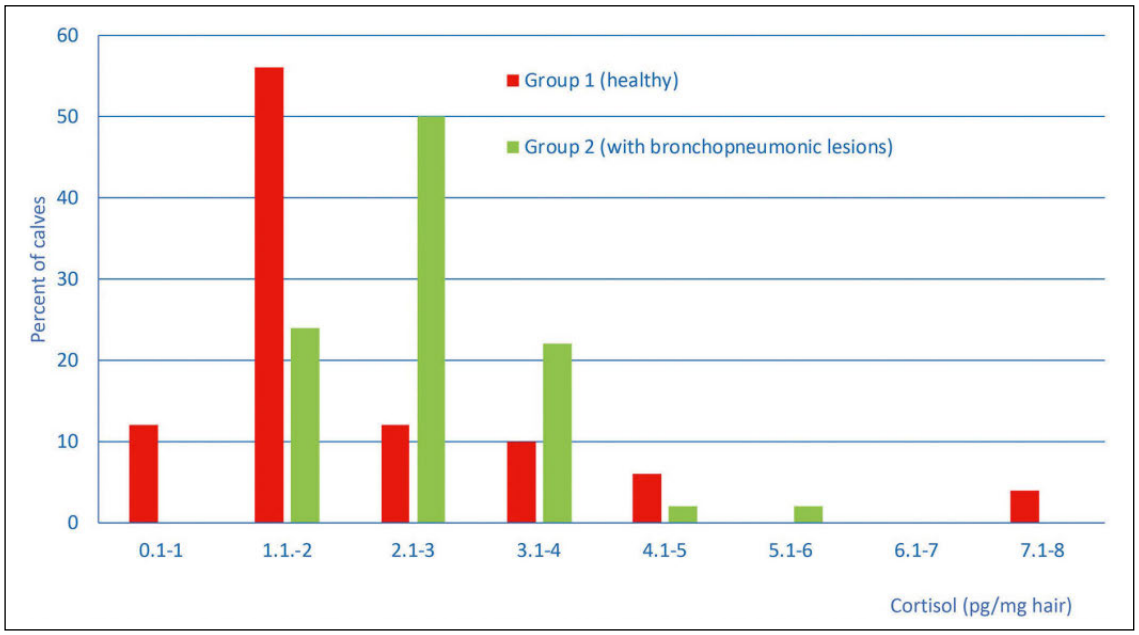

Fig.1: Frequency distribution of hair cortisol concentrations in 50 healthy calves and 50 calves with chronic bronchopneumonic lesions at slaughter. There was no significant difference between the frequency distributions of the two groups, and 97% of the hair cortisol concentrations was between 0.1 and 5.0 pg/mg hair.

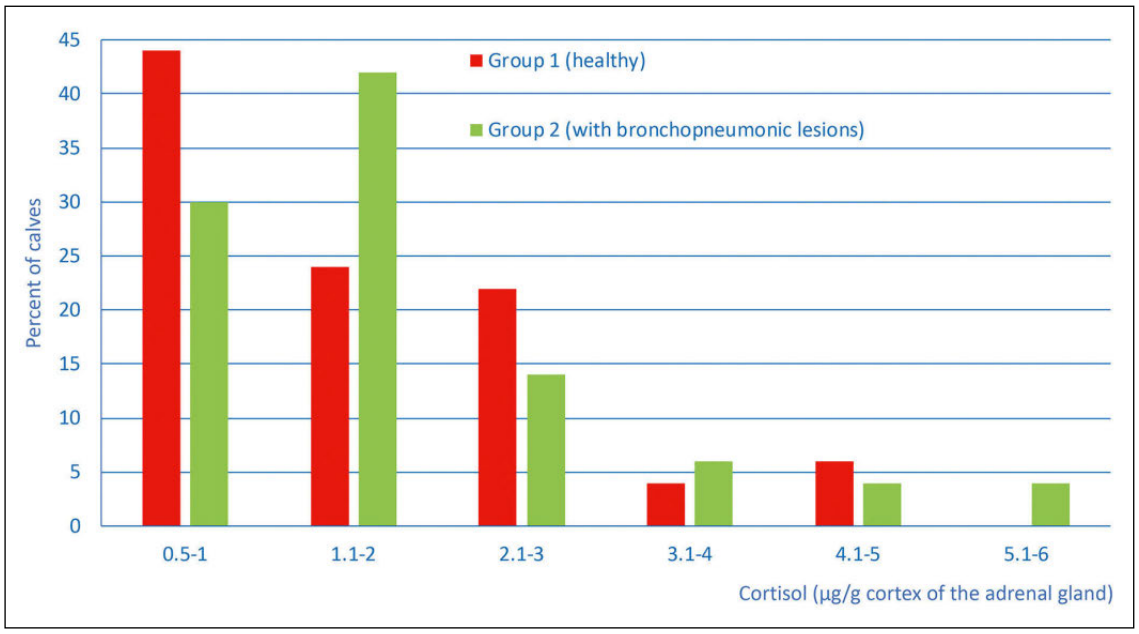

Fig. 2: Frequency distribution of adrenal cortical cortisol concentrations in 50 healthy calves and 50 calves with chronic bronchopneumonic lesions at slaughter. There was no significant difference between the frequency distributions of the two groups, and 98% of the cortisol concentration of the adrenal cortex was between 0.5 and 5.0 µg/g cortex.

group had numerically higher concentrations (1.9 vs. 1.6 pg/mg hair). A possible explanation for this is that the calves were not clinically ill despite pronounced chronic lung lesions. All calves underwent ante-mortem inspection and were determined fit for slaughter. Calves with bronchopneumonia involving more than one third of the lungs are usually clinically ill suggesting that the lung lesions in group 2 had healed and the clinical signs had resolved. Severely ill cows with bronchopneumonia that were euthanased because they did not respond to treatment had significantly higher hair cortisol concentrations than healthy cows (1.03 vs. 0.43 pg/mg hair).[4] Human patients with nonspecific chronic lung disease did not have higher hair cortisol concentrations than healthy individuals.[18] Similarly, cows with subclinical endometritis had the same hair cortisol concentrations as healthy cows,[8] but cows with metritis had higher concentrations.[12] Metritis represents a higher severity of

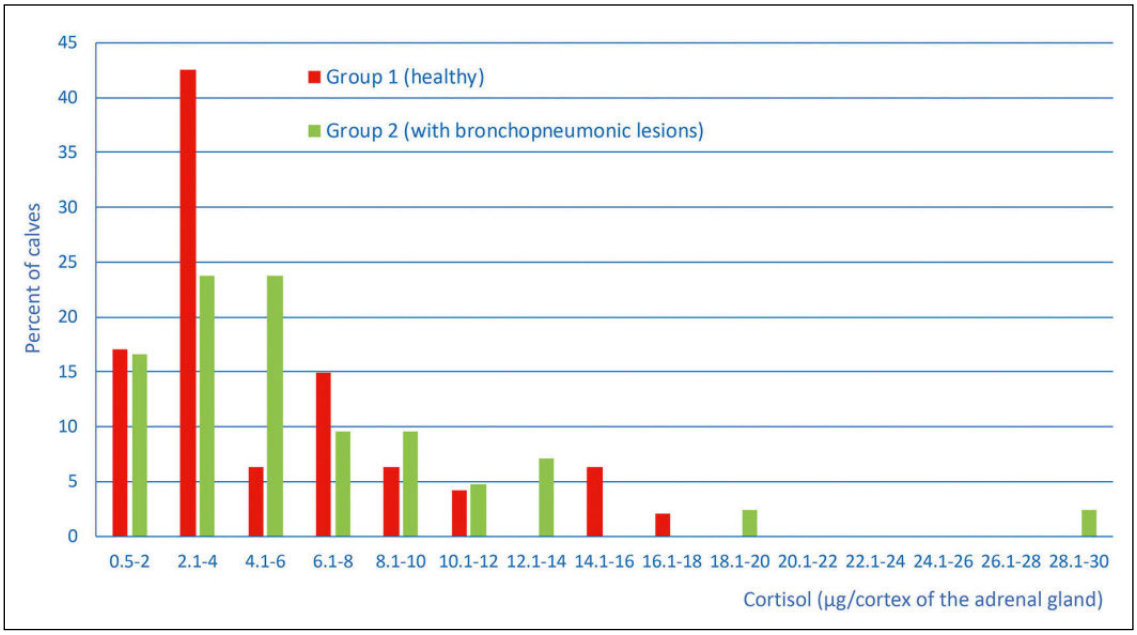

Fig. 3: Frequency distribution of the total adrenal cortisol content in 50 healthy calves and 50 calves with chronic bronchopneumonic lesions at slaughter. There was no significant difference between the frequency distributions of the two groups, and 90% of the total cortisol concentration of the adrenal cortex was between 2.1 and 12.0 µg/cortex.

illness than endometritis because all layers of the uterine wall are affected and the inflammatory lesions are not limited to the endometrium.[26] These observations suggest that the endogenous illness-related stress varies depending on the severity of the illness and that hair cortisol measurement is not suitable for the detection of stress situations of lower magnitude such as that generated by subclinical disease.[8] Therefore, not every condition results in stimulation of the hypothalamic-hypophyseal axis and consequently in an increase in cortisol secretion and deposition into hair. We could not determine whether the calves of this study had been treated for bronchopneumonia, but it can be assumed that initially the lung lesions were associated with clinical signs including coughing, nasal discharge, tachypnoea and/or fever, and that the calves had been treated. At the time of slaughter and hair sampling, the lung lesions were still evident but the clinical signs had resolved. Resolution of clinical signs was accompanied by partial or complete resolution of the endogenous disease-associated stress resulting in a non-significant increase in hair cortisol concentration in calves with bronchopneumonic lesions. Likewise, hair cortisol concentrations of cows treated for acute mastitis, lameness, metritis or colic returned to baseline one month later.[5]

As in previous studies,[6,28] the cortisol concentrations of the adrenal cortex and hair were not correlated in the present study. The total amount of adrenal cortisol did not differ between groups even though group 2 had numerically higher amounts. This was similar to the findings of studies in which the cortisol concentration of the adrenal cortex did not differ significantly between acutely and chronically ill cows[28] or between calves raised under different welfare production labels.[6,31] The adrenal cortex has limited storage capacity for cortisol, which is synthesised and secreted in response to ACTH stimulation.[19] This means that the total amounts of adrenal cortisol can be expected to be similar in individuals undergoing different stress levels.

The morphometric analyses did not aid in the differentiation of healthy calves and calves with bronchopneumonic lesions, which was similar to measurements made in acutely and chronically ill cows[28] and in veal calves reared under different welfare production labels.[6,28] Thus, morphometrical as well as endocrinological measurements can be omitted in future studies on the relationship between hair cortisol concentration and stress level.

The power of a test is the probability that the test will detect an effect,[9,15] i.e., the probability that the test rejects the null hypothesis when an alternative hypothesis is true. A power of 0.80 is considered a standard for adequacy and indicates an 80% chance of detecting an effect if one genuinely exists. If the power value is lower than 0.80, it may be increased by increasing the sample size. Depending on the variable, power values of the present study ranged from 0.05 to 1.00 and only the variables *adrenal cortisol content* and *weight of medulla* had values that exceeded 0.80. The statistical power for the principal variable of this study, namely the hair cortisol concentration, was only 0.25. To detect a significant

difference in hair cortisol concentration between calves with and without bronchopneumonic lesions, both groups would require a sample size of n=7'797, which would not be feasible logistically or financially. Furthermore, the large sample size suggests that the hair cortisol concentration is not critical for differentiating calves with and without bronchopneumonic lesions. However, the authors surmise that this would be different in calves with severe clinical bronchopneumonia and plan to investigate this in a follow-up investigation.

Conclusions

The results of the present study suggest that the hair cortisol concentration is not elevated in calves with chronic bronchopneumonic lesions in the absence of clinical signs of bronchopneumonia. To further test the hypothesis put forward, hair cortisol concentration in chronically ill calves with clinical signs of bronchopneumonia should be assessed and compared with values in healthy calves.

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Concentration de cortisol dans les poils des veaux abattus cliniquement en bonne santé avec et sans lésions broncho-pneumoniques chroniques

L'hypothèse de cette étude était que les veaux en bonne santé sont soumis à moins de stress et ont donc des concentrations de cortisol dans les poils plus faibles que les veaux présentant des lésions broncho-pneumoniques chroniques. Cinquante veaux sains (groupe 1) et 50 veaux présentant des lésions broncho-pneumoniques chroniques (groupe 2) ont été utilisés immédiatement après l'abattage, moment auquel des échantillons de poils et les deux glandes surrénales ont été prélevés. Les échantillons de poil et la glande surrénale gauche ont été utilisés pour la mesure du cortisol et la glande surrénale droite a été utilisée pour des examens histologiques et morphométriques. Les concentrations médianes de cortisol dans les poils des veaux des groupes 1 et 2 étaient respectivement de 1,6 et 1,9 pg/mg de poil et ne différaient pas significativement. Il en a été de même pour la concentration moyenne en cortisol de la glande surrénale (1,1 et 1,4 µg/g de tissu) et pour la teneur en cortisol surrénalien (3,7 et 4,6 µg). Les poids du cortex (3,3, moyenne et 3,5 g, médiane) et de la médulla (1,7 et 1,8 g, médiane) ne différaient pas significativement entre les groupes. Cette étude n'a pas mis en évidence de différences dans les concentrations de cortisol dans les poils et les surrénales entre les veaux abattus cliniquement en bonne santé avec ou sans lésions broncho-pneumoniques chroniques. Dans des études ultérieures, les veaux présentant des signes cliniques doivent être pris en compte.

Mots-clés: veau, poumon, bronchopneumonie, cortisol, poil, glande surrénale

Concentrazione di cortisolo nei peli dei vitelli da macello clinicamente sani, con e senza lesioni broncopolmonari croniche

L'ipotesi del presente studio era che i vitelli sani subiscono meno stress e quindi hanno concentrazioni di cortisolo nei peli inferiori ai vitelli con lesioni broncopolmonari croniche. Cinquanta vitelli sani (gruppo 1) e 50 vitelli con lesioni broncopolmonari croniche (gruppo 2) sono stati esaminati immediatamente dopo la macellazione e si sono prelevati campioni di peli ed entrambe le ghiandole surrenali. I campioni di peli e le ghiandole surrenali sinistre sono state utilizzate per la determinazione del cortisolo mentre le ghiandole surrenali di destra sono state utilizzate per esami istologici e morfometrici. Le concentrazioni mediane di cortisolo nei peli dei vitelli nei gruppi 1 e 2 erano di rispettivamente di 1,6 e 1,9 pg/mg di peli e non differivano significativamente. Lo stesso valeva per la concentrazione media di cortisolo nelle ghiandole surrenali (1,1 e 1,4 µg/g di tessuto) e per il contenuto di cortisolo surrenale (3,7 e 4,6 µg). I pesi della corteccia (3.3, media e 3.5 g, mediana) e del midollo (1.7 e 1.8 g, entrambi mediane) surrenale non differivano significativamente tra i gruppi. Questo studio non ha rilevato differenze nelle concentrazioni di cortisolo nei peli e nelle ghiandole surrenali tra vitelli da macello clinicamente sani affetti o no da lesioni broncopolmonari croniche. In ulteriori studi, dovrebbero essere presi in considerazione anche dei vitelli con segni clinici.

Parole chiave: vitello, polmone, broncopolmonite, cortisolo, pelo, ghiandola surrenale

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