Effect of Nutrition, Lactation and Periparturient Complications on Adrenal, Pituitary and Ovarian Function and Uterine Involution in High-Producing Dairy Cows

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Abstract

Effects of body condition at parturition, purperal complications, milk yield and parity on the sequential changes in postpartum adrenocortical and pituitary functions, ovarian activity and uterine involution were investigated in 44 high-producing Holstein Friesian cows. One half of the cows had normal adrenocortical function and the other half had either enhanced or depressed adrenocortical function 8 days postpartum. The adrenocortical function was found to be normal in all cows 22 days after calving. Pituitary gland response to GnRH was low in 68.2 % of cows 7 days after parturition and 31.8 % still had low response 21 days postpartum. A significant negative correlation ($P<0.05$)was observed between basal and ACTH-stimulated plasma cortisol levels and GnRH-stimulated plasma luteinizing-hormone levels 7 to 8 days after calving. Multifactorial analysis of variance showed that postpartum adrenocortical function was enhanced by poor body condition at calving, high milk yield, and increased parity. In association with enhanced adrenocortical function, pituitary function tended to be depressed 7 days postpartum in cases of poor body condition, high milk yield and increased parity. Among all the various factors examined, milk yield had the most significant effect on postpartum adrenocortical and pituitary functions. Uterine involution tended to be delayed in cows with poor body condition at calving, high milk yield and increased parity. It may be concluded that undernutrition, high milk yield and increased parity are predominant factors causing enhancement of adrenocortical function which is associated with depression of pituitary function.

Introduction

It has been reported that a variety of stresses had deleterious effects on female reproductive efficiency. The effects of stress on reproductive performance is particularly important in the dairy cow. The stresses might include managerial, enviromental, metabolic, nutritional and common reproductive disorders. Reports had already been made on the subsequent lowered reproductive performance of cows with dystocia and puerperal complications, high milk yield, poor body condition, and increased parity. It is generally assumed that these periparturient complications and other endocrinological dysfunction lead to a lowered fertility level. However, this assumption has not been well proved.

The main objectives of the present reports are firstly to describe sequential changes in the postpartum adrenocortical and pituitary functions, ovarian activity and uterine involution in dairy cows, and secondly to examine the effects of condition of parturition, body condition at calving, puerperal complications, milk yield and parity on postpartum adrenocortical and pituitary functions, ovarian activity and uterine involution.

Materials and Methods

Forty-four pregnant Holstein Friesian cows from the dairy herd of the Rakuno Gakuen University, Ebestu, Hokkaido were used in this study. The age of the cows

ranged from 2 to 9 years with a mean (± S.D.) of 3.7 ± 1,7 years. There were 14 primiparous and 30 pluri-parous cows. Average milk yield per head per lactation in the herd was about 8,700 kg.

Adrenocorticotropic hormone (ACTH) challenge test was conducted at 8 and 22 days postpartum. Twenty-five i.u. of ACTH (Cortrosyn Inj., Daiichi Pharmaceutical Co.) were administered intramuscularly. About 5 to 10 ml of blood was collected via coccygeal vein puncture into heparinized test tubes 15 minutes before and immediately before ACTH injection and 60 min after the injection.

Plasma cortisol concentrations were determined by a double antibody enzyme immunoassay. The basal cortisol concentration was defined as : 1) normal if the cortisol value was less than 5 ng/ml, and 2) elevated if 5 ng/ml or higher. The type of adrenocortical response to ACTH was defined as : 1) depressed or low response if peak cortisol concentration was less than 15 ng/ml, and 2) normal or medium response if between 15 and 50 ng/ml, and 3) enhanced or high response if higher than 50 ng/ml.

Pituitary function was evaluated by GnRH challenge tests performed on days 7 and 21 postpartum. Fifty mcg of GnRH analog (fertirelin acertate, Takeda Chemical Industries, Ltd.) were injected intramuscularly. Blood was collected by coccygeal vein puncture into heparinized test tubes 30 min before and immediately before injection, as well as 1, 2 and 5 hrs after injection.

Plasma LH concentrations were determined by a double antibody radioimmunoassay. The criteria for the classification of the type of pituitary response to GnRH were defined as : 1) low response if peak LH concentrations were below 5 ng/ml, 2) medium response if between 5 and 10 ng/ml, and 3) high response if above 10 ng/ml.

Postpartum ovarian function, with emphasis on the interval from calving to first ovulation, was monitored by three times weekly milk progesterone assays during the first month after parturition.

Progesterone concentrations in skim milk were determined by a double antibody enzyme immunoassay. The increase in progesterone concentration in skim milk of 1.0 ng/ml or higher and the continuation of its increase for at least 5 days was considered as an indication of ovulation and corpus luteum formation.

Gross uterine involution postpartum was examined by weekly palpation per rectum and ultrasonographic examination. Uterine swabs for bacteriological examination were obtained at 14 and 28 days post-partum.

Analysis of variance (least squares method, General Linear Models Procedure of the Statistical Analysis System) were used for determining the effects of the different factors on plasma cortisol and LH concentrations. Differences in values among the various conditions in each individual factor was also analyzed by Student's t-test. Correlation analysis by Pearson's correlation coefficient were used to examine relation-ships between the log-transformed cortisol and LH values. Chi-square test was used for the comparison of the percentages.

Results

1. Postpartum adrenocortical and pituitary functions, ovarian activity and uterine involution in cows

The adrenocortical and pituitary functions, ovarian activity and uterine involution in 44 postpartum cows are summarized and presented in Figure 1.

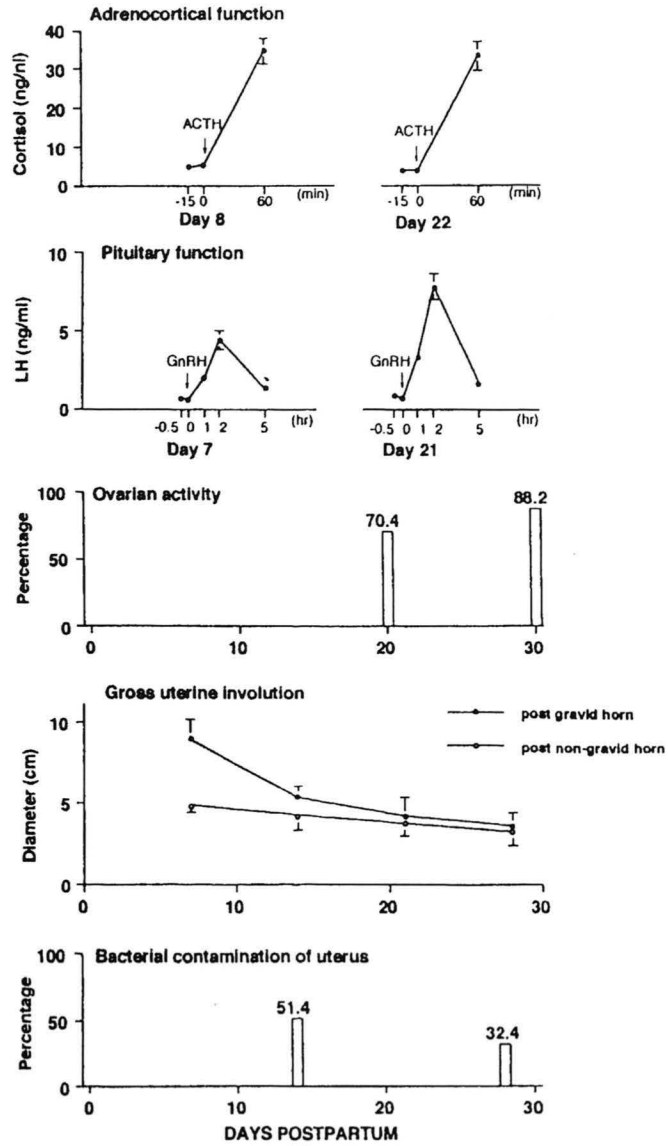

Figure 1. The postpartum adrenocortical and pituitary functions, ovarian activity and uterine involution in 44 dairy cows.

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Cows, in general, had enhanced adrenocortical function at 8 days postpartum which might be responsible for depressed pituitary function the day before. The once enhanced adrenocortical function returned to normal at 22 days and this was associated with increased pituitary responsiveness to GnRH at 21 days after calving. The recovery of pituitary function could have resulted in the occurrence of first ovulation in the majority of cows 20 to 30 days postpartum. In the meantime, uterine involution also took place.

(1) Postpartum adrenocortical function

Of 44 cows, 10 cows (27.7 %) had enhanced adrenocortical function, 24 cows (54.5 %) had medium or normal function and 10 cows (27.7 %) had depressed function at 8 days postpartum. In cows with enhanced and normal adrenocortical function at 8 days postpartum, a slight decrease of basal plasma cortisol concentrations and same levels of magnitude of cortisol response to ACTH were shown at 22 days postpartum.

Cows with depressed adrenocortical function at 8 days postpartum still had a low basal cortisol concentration at 22 days, but recovered the adrenal response to ACTH.

(2) Postpartum pituitary function

Cows were classified into three groups, according to the LH response to GnRH. On day 7, 30 (68.2 %) of the 44 cows had low response, 12 (27.3 %) had medium or optimum LH response, and 2 (4.5 %) had high LH response. On day 21, the number of cows with low LH response decreased to 14 cows (31.8 %), and those with medium and high LH response increased to 17 cows (38.6 %) and 13 cows (29.5 %), respectively. There were significant differences between the percentages of cows with low and high pituitary response to GnRH at 7 and 21 days postpartum ($P<0.01$).

(3) Postpartum ovarian activity

Days of first ovulation after calving, as determined by milk progesterone assay, varied between 8 and 28 days. Thirty-one (70.4 %) cows showed first ovulation within 20 days, and another 8 (18.2 %) within 30 days after parturition. Five (11.4 %) did not ovulate within 30 days.

(4) Uterine involution

Gross uterine involution: Gross uterine involution was completed within 30 days in 34 (77.3 %) of 44 cows. The relative diameters of the post gravid and non-gravid uterine horns were compared during the first 30 days postpartum and showed similarity in size starting at 21 days postpartum (Figure 1).

Uterine bacterial contamination: At 14 days postpartum, 18 (51.4 %) of 35 uterine swab samples yielded 23 bacterial isolates and at 28 days postpartum, 11 (32.4 %) of 34 samples yielded 13 bacterial isolates (Figure 1). The 3 most common bacterial isolates were *Actinomyces pyogenes, Streptococcus spp.*, and *Escherichia coli.*

2. Effects of dystocia, body condition, puerperal complications, milk yield and parity on postpartum adrenal and pituitary functions, ovarian activity and uterine involution

(1) Effect on adrenal and pituitary functions

Results of analysis of variance (least-squares method, General Linear Models procedure) showed that milk yield had the predominant effect on adreno-cortical as well as pituitary functions (Tables 1 and 2). High milk yield increased ACTH-stimulated plasma cortisol concentrations at 8 days ($P<0.10$) and 22 days ($P<0.05$) postpartum. High milk yield was also associated with low basal plasma LH concentrations at 7 days ($P<0.01$) and 21 days ($P<0.05$) post-partum. Parity and body condition score at calving were also found to have significant effects on basal plasma LH concentrations.

Table 1. Analysis of variance for basal and ACTH-stimulated plasma cortisol concentrations 8 and 22 days postpartum.

Sources of	df	F-values 8 d		22d	
		Basal	Response	Basal	Response
Parity	1	0.29	0.16	0.18	1.90
BCS	1	0.04	0.74	0.34	2.20
Puerperium	1	0.22	0.13	0.01	1.59
Milk yield	1	1.82	3.48†	2.55	7.04*

† $P<0.10$

* $P<0.05$

Table 2. Analysis of variance for basal and GnRH-stimulated plasma LH concentrations 7 and 21 days postpartum.

Sources	df	F-values 7 d		21 d	
		Basal	Response	Basal	Response
Parity	1	6.13*	1.67	2.21	1.53
BCS	1	4.66*	0.10	3.57†	1.85
Puerperium	1	0.38	0.15	0.05	0.04
Milk yield	1	8.30**	0.21	5.40*	0.17

† $P<0.10$

* $P<0.05$

** $P<0.01$

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Analysis by Pearson's correlation coefficients revealed a significant correlation between milk yield for 7 days and log-transformed ACTH-stimulated cortisol value at 8 days postpartum ($r=0.31$, $P<0.05$), and milk yield for 21 days and log-transformed basal cortisol value at 22 days postpartum ($r=0.31$, $P<0.05$).

Thus, milk yield was shown to be the most predominant factor which caused enhancement of adrenocortical function and depression of pituitary function in postpartum cows.

(2) Effect on ovarian activity and uterine involution

Effects of each of various factors on postpartum ovarian activity and uterine involution were investigated individually by comparing percentages among different groups.

Effect of dystocia: The percentages of cows that resumed ovarian activity did not differ significantly between dystocia and normal calving groups. The percentages of cows completing uterine involution within 30 days postpartum showed a tendency for cows with dystocia to have delayed gross uterine involution.

Effect of body condition at calving: Cows in poor body condition at parturition showed higher percentage of cows completing gross uterine involution within 30 days postpartum, whereas the cows in poor condition showed higher percentage of cows having uterine bacterial contamination at 28 days postpartum than those in good condition.

Effect of puerperal complications: There was a significant difference in percentages of cows completing gross uterine involution within 30 days postpartum between cows with reproductive and/or metabolic disorders and those without any complications ($P< 0.01$). Gross uterine involution was completed in all of the normal cows during this period, while 60 to 66.7 % of cows with puerperal complications completed gross uterine involution.

Effect of milk yield: The percentage of cows which resumed ovarian ovarian cyclicity was slightly higher in cows with high milk yield than cows with low and medium milk yield. Completion of gross uterine involution was observed in more cows with low and medium milk yield than in cows with high milk yield.

Effect of parity: There was a lower percentage of pluriparous cows that have completed gross uterine involution by 30 days postpartum than primiparous cows ($P<0.10$).

Discussion

Only limited data on adrenocortical responsiveness to ACTH have been available in postpartum cows. Previous researchers[1,2] reported that there was no significant change in adrenocortical response to ACTH during postpartum period and that there was considerable animal to animal variation in adrenal response. In this study the classification of adrenocortical response based upon the basal and ACTH-stimulated plasma cortisol concentrations allowed the demonstration of altered adrenocortical function in cows at 8 days postpartum. The results of the study revealed that only about half of the cows had normal adrenocortical function and the other half had either enhanced or depressed adrenocortical function.

It has been reported previously that the resumption of pituitary function occurs within 7 to 10 days postpartum when basal plasma LH concentrations[3] and the pituitary gland responsiveness to exogenous GnRH (4.5) returns to normal. However, individual variation of pituitary function in postpartum cows has not been well described. In the present study, characterization of the pituitary gland response to GnRH revealed that 68.2 % and 31.8 % of the cows had low LH response at 7 and 21 days postpartum, respectively. These results indicate that the rate of resumption of pituitary function is relatively low at 7 days postpartum and still not completed in about a third of the cows at about three weeks after calving.

The significant negative correlation was observed between basal and ACTH-stimulated plasma cortisol concentrations and plasma LH concentrations about a week after parturition in this study. More specifically, cows with enhanced adrenocortical function had the lowest magnitude of pituitary response to GnRH, while cows with depressed adrenocortical function had the highest magnitude of pituitary LH response. It has already been reported that stress in dairy heifers during the follicular phase increased adrenal activity as monitored by plasma cortisol concentrations and inhibited gonadotropin secretion.

Observations from the present and previous studies suggest that stress could enhance adrenocortical function and depress pituitary function in both cycling and early postpartum cows. The apparently inhibitory effects of increased or enhanced adrenocortical function on pituitary LH secretion was only noted during the first week after calving. It is possible that after the first 7 to 10 days, other factors such as the reported more frequent episodes of endogenous GnRH release and the subsequent estradiol rise from increased follicular activity help override the inhibitory effects of increased adrenocortical function and plasma cortisol concentrations on the pituitary response to GnRH.

The effects of the different factors on postpartum adrenocortical and pituitary functions were investigated by multifactorial analysis of variance. It was shown that milk yield had significant effects on both adreno- cortical and pituitary functions. Effects of parity, BCS and

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milk yield on pituitary function were also significant.

Suggested optimal BCS during the dry period is 3.5 to 4.0. In the present study, 52.3 % of the cows examined had less than the optimal BCS. Poor body condition at calving was associated with slight enhancement of adrenocortical function at 8 days post-partum and slight depression in pituitary function. However, no significant differences in ovarian activity and uterine involution were observed between cows in poor and optimal body condition. The enhancement of adrenocortical function in cows with poor body condition may be due to the metabolic response of the body during energy restriction. A shortage of energy may enhance beta-endorphin release from the hypothalamus or anterior pituitary gland which is related to the stimulation of appetite and dietary intake. Enhanced release of beta-endorphin may exert inhibitory effects on GnRH release and pituitary LH release.

Cows with high milk yield consistently had higher basal plasma cortisol and ACTH-stimulated plasma cortisol concentrations than cows with low milk yield. This indicates that a prolonged lactation demand for increased milk yield may enhance adrenocortical function. Adrenocortical hormones are known to play an important role in lactogenesis and galacto-poiesis in cows. It may be logical that cows with high milk yields have more enhanced adrenocortical function during the early lactation period. An apparent depression in pituitary function was also observed in cows with high milk yield.

Several studies have reported that increased milk yield tends to delay uterine involution[6] and may prolong the interval from parturition to first ovulation.[7] In the present study an apparent delay in uterine involution was noted in cows with high milk yield. However, there was no apparent adverse effect on ovarian function. This finding is in agreement with the results of other studies which showed no association between milk yield and onset of ovarian cyclicity[8,9] Butler *et al.*[9] reported that the average energy balance during the first 20 days of lactation was inversely related to days to first ovulation and to milk yield. Milk production during this period, however, was not closely related to days to first ovulation. Thus, milk yield appears to affect postpartum adrenocortical and pituitary functions, as well as uterine involution, but it may not be a determining factor affecting postpartum ovarian activity.

It may be concluded that about 50% of cows at 8 days postpartum had either enhanced or depressed adrenocortical function which showed a significant effect on pituitary function. Parity, BCS at calving, and milk yield were associated with enhanced adreno-cortical and depressed pituitary function and delayed uterine involution, high milk yield being the most predominant factor.

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