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Blood profiles in dairy cows with displaced abomasum

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ABSTRACT

An observational study was carried out in Swedish dairy herds to investigate differences between cows with and without displaced abomasum (DA), in concentrations of glucose, insulin, fructosamine, nonesterified fatty acids (NEFA), β-hydroxybutyrate, cholesterol, haptoglobin, increased enzyme activity of aspartate aminotransferase and glutamate dehydrogenase, and the revised Quantitative Insulin Sensitivity Check Index (RQUICKI). A secondary aim was to study how blood profiles for DA cows vary with time in relation to calving. Sixty-nine DA cows within 2 to 56 d postpartum, in 60 herds, were clinically examined and blood samples were drawn at the time DA was diagnosed. At the same time, 104 healthy control cows matched by herd and stage of lactation were also sampled. The blood parameters were studied using mixed linear models, including herd as a random effect, and DA (case or control), parity, breed, sampling time in relation to calving, other diseases, and the interaction between DA and time as fixed effects. Concentrations were higher in DA cows than in control cows for NEFA (least squares means 1.36 vs. 0.34 mmol/L), β-hydroxybutyrate (1.56 vs. 0.90 mmol/L), aspartate aminotransferase (1.96 vs. 0.97 μkat/L), glutamate dehydrogenase (197 vs. 78 μkat/L), and haptoglobin (0.76 vs. 0.17 g/L), whereas concentrations were lower in DA cows than in control cows for insulin (3.61 vs. 8.48 mU/L) and cholesterol (3.04 vs. 3.75 mmol/L). Glucose (2.83 vs. 2.79 mmol/L) and fructosamine (266 vs. 252 μmol/L) concentrations were similar in both groups; however, a tendency toward lower RQUICKI values (0.42 vs. 0.46) in the DA cows was found, indicating reduced insulin sensitivity. For most blood parameters, differences between DA cows and controls remained constant over time. Seventy-two percent of the DA cows had at least one other disease in the period from 1 wk antepartum to 1 wk after the DA was diagnosed. Haptoglobin could potentially be used to detect treatable infectious or inflammatory conditions in the early postpartum period, possibly reducing the incidence of DA. Consequently, there were major changes in blood profiles in cows with DA compared with healthy control cows, indicating a negative energy balance, liver cell damage, and an inflammatory response. The results contribute to an understanding of the metabolic changes in DA cows.

Key words: dairy cow, displaced abomasum, blood profile, revised Quantitative Insulin Sensitivity Check Index

INTRODUCTION

Displaced abomasum (**DA**) in dairy cows is a multifactorial disease, with the majority of cases being diagnosed within the first week postpartum (**pp**) (Stengärde and Pehrson, 2002; Doll et al., 2009). Most cows are in a negative energy balance around calving and this state has been suggested to be a risk factor for DA (Cameron et al., 1998). However, the metabolic load on the cow varies over time during the first month pp, and blood profiles in DA cows may therefore show differences due to time from calving. Displaced abomasum has also been associated with other diseases such as retained placenta, metritis, and ketosis (Rohrbach et al., 1999), as well as with hepatic lipidosis (Bobe et al., 2004).

Increased blood concentrations of NEFA, BHBA, haptoglobin, and increased enzyme activity of aspartate aminotransferase (**AST**) and glutamate dehydrogenase (**GD**) (Muylle et al., 1990; Hirvonen and Pyörälä, 1998; Itoh et al., 1998; Komatsu et al., 2002; Zadnik, 2003), as well as decreased concentrations of total cholesterol (Rehage et al., 1996; Itoh et al., 1998; Komatsu et al., 2002) have been reported in cows having a DA. Findings regarding glucose and insulin concentrations have been inconsistent (van Meirhaeghe et al., 1988; Itoh et al., 1998; Komatsu et al., 2002; Stengärde and Pehrson, 2002; Van Winden et al., 2003; Zadnik, 2003; Pravet-

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toni et al., 2004). Fructosamine may have an advantage over glucose when monitoring for DA risks at the herd level (Herdt, 2000b), because serum concentrations of fructosamine provide a retrospective record of blood glucose concentrations during the previous 1 to 3 wk (Ropstad, 1987). Along with high concentrations of glucose, reduced insulin sensitivity has been proposed as a prerequisite for DA (van Meirhaeghe et al., 1988; Pravettoni et al., 2004). In humans, the revised Quantitative Insulin Sensitivity Check Index (**RQUICKI**), an index based on NEFA, glucose, and insulin concentrations in plasma, is used to determine insulin sensitivity (Perseghin et al., 2001; Rabasa-Lhoret et al., 2003). The RQUICKI value has been shown to be negatively associated with body condition (Holtenius and Holtenius, 2007) and insulin sensitivity (Bossaert et al., 2009) in dairy cows, although in one study, insulin-resistant cows did not have lowered RQUICKI values (Kerestes et al., 2009).

Most cows with DA are treated in their own herds, but in most studies, DA cows are sampled after transport to a clinic (Itoh et al., 1998; Komatsu et al., 2002; Zadnik, 2003), while control cows are sampled either in the original herds (Itoh et al., 1998) or in other herds (Muylle et al., 1990; Zadnik, 2003). In addition, some studies have not used control cows, but instead use reference values for comparison (Rehage et al., 1996; Hirvonen and Pyörälä, 1998; Stengärde and Pehrson, 2002). Transport, change of management, and change in feed can affect several blood parameters, and DA and control cows should therefore be sampled under comparable conditions. Consequently, available comparisons of blood parameters in cows with and without DA may not always be valid. It was therefore of interest to conduct an observational study in which DA cows are clinically examined and blood-sampled close to diagnosis, using concurrent control cows in the same herds and evaluating a wide range of blood parameters at different time points relative to calving. To our knowledge, few such studies (e.g., LeBlanc et al., 2005) have been published.

The objective of this study was therefore to compare blood parameters that reflect metabolic disturbances and liver cell damage in dairy cows with and without DA under field conditions, and to study how blood profiles for DA cows vary with time in relation to calving.

MATERIALS AND METHODS

Data Collection

The study, including the handling of animals, was approved by the local ethics committee in Uppsala, Sweden. Between January 2005 and July 2007, veterinary practitioners at 14 ambulatory practices across Sweden were asked to examine and collect blood samples from cows diagnosed with DA, on the day of diagnosis, and from 2 healthy control cows in the same herds. The cows had to be within 1 mo pp and control cows were selected according to their calving date, which was to be as close as possible to the calving date of the cows with DA. For practical reasons, we chose to include cows sampled within 2 mo pp. Cases were defined as having displacement of the abomasum to the left or right with or without suspected torsion. The diagnosis was based on a clinical examination by the veterinarian including auscultation to locate the characteristic metallic ping sounds found in cows with DA. Samples were collected from 78 cows with DA and from 134 control cows. Twelve cows were excluded because of missing identities (3 cows) or because they were sampled accidentally before calving (3 cows) or during mid or late lactation (6 cows). Seventeen control cows with a previous disease during the current lactation and 1 cow with a right-sided DA (with a glucose value of 36.8 mmol/L), treated with corticosteroids and calcium intravenously on the day of sampling, were also excluded. Finally, 2 DA cows and 6 controls sampled on day of calving or 1 d pp were also excluded because the sample size for this idiosyncratic period was too small to handle separately in the analyses. A total of 69 cows with DA (1 to 23 cases per practice) and 104 control cows from 60 herds were included in the study.

A questionnaire was completed by the practitioner and included cow identity, date of visit, cow breed, parity, and body condition. Body condition was scored as thin, medium, or fat. For the DA cows, type of displacement (left- or right-sided), duration of symptoms (in days), general condition, feed intake, other diseases (concomitant diseases or diseases contracted between calving and the day of sampling), and treatments were recorded. Duration of symptoms was defined as the number of days the farmer had noticed a reduced feed intake, decreased milk yield, or an affected general condition before DA was diagnosed by the veterinarian. General condition was defined as normal, or as mildly, moderately, or severely disturbed at the time of sampling. Feed intake was defined as normal or lowered, specifying whether forage, concentrates, or both were being rejected. Treatments with calcium per orally or intravenously, per oral infusion to increase blood glucose concentration (e.g., propylene glycol), corticosteroids, or antibiotic treatments during the week before sampling were also recorded. Data were retrieved from the Swedish Official Milk Recording Scheme (Olsson et al., 2001), including herd size and mean milk yield, and cow breed, parity, date of calving, and disease records.

Table 1. Distribution of observations, by predictor variables in 69[1] cows with displaced abomasum (DA cows) and 104 controls

Characteristic	DA cows	Controls
Breed		
Swedish Holstein	45	55
Swedish Red	21	35
Other[2]	3	14
Parity		
1	5	21
2	24	38
≥3	40	45
Other disease[3]		
No	19	104
Yes	50	0
Sampling time		
2 to 14 d pp[4]	32	47
15 to 28 d pp	32	39
29 to 56 d pp	5	18

[1]Sixty left-sided displacements, 7 right-sided displacements, and 2 right-sided displacements with suspected torsion.

[2]Other breeds or cross-breeds.

[3]Previous or concurrent diseases from 1 wk antepartum to 1 wk after sampling time.

[4]Postpartum.

Blood Samples

Blood from either the jugular vein or the coccygeal vessels was collected from each cow in evacuated tubes, both without additives and with heparin fluoride (BD Vacutainer Systems, Plymouth, UK). The blood samples were refrigerated until centrifugation, and serum and plasma were frozen within 8 h of sampling. Samples were stored at −20°C until analysis.

Blood samples were analyzed at the Clinical Pathology Laboratory, University Animal Hospital, Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden, using commercial kits. Serum haptoglobin (Phase Range Haptoglobin Assay; Tridelta Development Ltd., Bray, Ireland) and BHBA (β-Hydroxybutyrate Liqui-Color procedure no. 2440; Stanbio Laboratory, Boerne, TX) were measured on a Cobas Mira chemistry analyzer (Roche Diagnostica, Basel, Switzerland). Serum activities of AST (AST/GOT IFCC, Konelab, Thermo Electron Corporation, Vantaa, Finland), GD (GLDH, Roche Diagnostics GmbH, Mannheim, Germany), as well as concentrations of total cholesterol (Konelab, Thermo Electron Corp.), NEFA (NEFA C, Wako Chemicals GmbH, Neuss, Germany), fructosamine (Fructosamine, ABX Pentra, Montpellier, France), and plasma glucose (Glucose, HK, Konelab, Thermo Electron Corp.), were determined using a Konelab 30 chemistry analyzer (Thermo Electron Corp.). Serum insulin was analyzed with a porcine insulin RIA (Porcine Insulin RIA Kit, Linco Research, St. Charles, MO), previously evaluated for bovine samples, using a Cobra II Auto-Gamma counter (Packard Instrument Company, Meriden, CT). Intraassay and interassay coefficients of variation for the RIA were 5.7 and 3.1%, respectively.

Statistical Analysis

A metabolic index was calculated as RQUICKI = $1/[\log_{10}(\text{glucose, mg/dL}) + \log_{10}(\text{insulin, } \mu\text{U/mL}) + \log_{10}(\text{NEFA, mmol/L})]$ (Perseghin et al., 2001; Rabasa-Lhoret et al., 2003). All outcome variables were measured on a continuous scale, but were transformed to obtain normally distributed residuals. Log_{10} transformations were used for AST, BHBA, fructosamine, GD, haptoglobin, insulin, and NEFA. The RQUICKI was converted to an inverted scale, and the square root was used to transform cholesterol and glucose.

Linear mixed models were used to investigate associations between DA and blood parameters, using the MIXED procedure of SAS (SAS version 9.2, SAS Institute, Cary, NC). The model used was

$$\text{Blood parameter} = \text{DA} + \text{Parity} + \text{Breed} + \text{Other disease} + \text{Sampling time} + \text{DA} \times \text{Sampling time} + \text{Herd}.$$

Fixed explanatory variables were DA (case or control), parity (1, 2, or ≥3), breed (Swedish Holstein, Swedish Red, or other), other disease (with or without other disease from 1 wk antepartum to 1 wk after day of sampling), sampling time (classified as d 2 to 14 pp, d 15 to 28 pp, or d 29 to 56 pp), and the interaction between DA and sampling time. Herd was included as a random effect to account for clustering of within-herd observations. The distribution of observations by the predictor variables is shown in Table 1. Least squares means and their 95% CI were calculated for DA cows and controls and back-transformed to the original scale, testing the differences by an *F*-test. For visual comparison between DA and control cows over time, separate least squares means and their 95% CI were constructed for each sampling time.

Identical models, including only left-sided DA cases, generated similar model estimates; therefore, all DA cases were kept in the final analyses. All models were also tested by redefining other disease to include diseases 1 wk before to 1 wk after sampling. Model estimates changed only for cholesterol, and the original definition of other disease was therefore retained.

Within DA cows, additional analyses were performed to evaluate the effect of duration of symptoms on blood parameters. The model used was

$$\text{Blood parameter} = \text{Parity} + \text{Breed} + \text{Other disease} + \text{Sampling time} + \text{Duration} + \text{Herd}.$$

Table 2. Herd and cow characteristics for 60 herds with 69[1] cows with displaced abomasum (DA) and 104 healthy controls sampled within 2 to 56 d postpartum

Item	Mean	SD	Range
Herd size, cows	84	71	15–467
Milk yield (kg of ECM/cow and yr)	9,501	1,106	6,068–11,531
Day of sampling pp[2]			
DA cows	16	10.2	0–55
Controls	19	11.7	0–51
Parity, lactations			
DA cows	2.9	1.2	1–6
Controls	2.5	1.3	1–6

[1]Sixty left-sided displacements, 7 right-sided displacements, and 2 right-sided displacements with suspected torsion.

[2]Postpartum.

In addition to the fixed explanatory variables listed previously, these models also included duration of symptoms (classified as 1 to 3 d; n = 25, or >3 d; n = 42) and sampling time was reclassified as 1–2 wk pp or >2 wk pp because of the limited number of observations included in these analyses. Similarly, additional models evaluated the effect of medical treatment according to the following model:

$$\text{Blood parameter} = \text{Parity} + \text{Breed} + \text{Other disease} + \text{Sampling time} + \text{Treatment} + \text{Herd},$$

where treatment was classified as no treatment (n = 19 or treatment with at least one of the following: calcium, per oral infusions to increase blood glucose concentration, corticosteroids, or antibiotics (n = 48).

Model validation was carried out by examination of residuals, with respect to homogeneity of variance and a normal distribution, and all models were found to be valid. A coefficient of determination (R^2) was approximated by the squared correlation between observed and predicted values (Dohoo et al., 2003).

RESULTS

Herd and Cow Characteristics

Herd and cow characteristics for DA cows and controls are shown in Table 2. Body condition was reported as thin, medium, and fat in 29, 35, and 4 DA cows, and in 5, 84, and 8 control cows, respectively. General condition was reported in 66 DA cows, 2 of which had normal general condition, and 31 had mildly, 29 had moderately, and 4 had greatly disturbed general conditions. Heart rate was reported in 51 DA cows, with a mean of 73 (SD 14; range 40 to 100) beats per minute. In 68 cows with DA, disturbed feed intake was reported. Most cows rejected both forage and concentrates (43 out of 58 cows with records). Duration of symptoms was reported in 67 DA cows. Twenty-five cows had symptoms for 1 to 3 d, 23 cows for 4 to 7 d, and 19 cows for 8 to 26 d.

Fifty (72%) of the DA cows had at least one other disease in the period from 1 wk antepartum to 1 wk after sampling. Of the 50 DA cows with other disease, 16 cows had 1, 21 had 2, 11 had 3, and 2 had 4 diagnoses. The most commonly reported diseases in the cows with DA were endometritis or metritis, retained placenta, ketosis, unspecified disorders related to the gastrointestinal tract, and puerperal paresis. Fifty of the DA cows were treated within the last week before sampling; that is, before diagnosis. Of these, 19 cows were treated with calcium per orally or intravenously, 29 with per oral infusions to increase blood glucose, 13 systemically with corticosteroids, and 18 with antibiotics. Three cows were treated both orally to increase blood glucose, and with corticosteroids.

Blood Parameters

The overall effect of DA was significant for insulin, NEFA, cholesterol, AST, GD, and haptoglobin. A tendency toward lower RQUICKI values was seen, but glucose and fructosamine were not significantly different for DA cows and controls (Table 3). The effect of the interaction between DA and sampling time was significant for glucose ($P = 0.028$) and BHBA ($P = 0.0098$). Duration of symptoms and medical treatments were not significantly associated with any of the blood parameters (results not shown). The approximate R^2 indicates that the models explained from 9% (glucose) to 70% (cholesterol) of the total variability (Table 3).

Estimated effects of DA and sampling time on glucose, fructosamine, insulin, RQUICKI, NEFA, BHBA, cholesterol, AST, GD, and haptoglobin are shown in Figures 1, 2, and 3. For insulin, NEFA, BHBA, cholesterol, AST, GD, and haptoglobin, significant differ-

Table 3. Least squares means, their 95% confidence intervals, and *P*-values, for comparisons of blood parameters between cows with displaced abomasum (DA) and controls, estimated using linear mixed models, and the coefficient of variation (R^2) for each model

Parameter	DA cows	95% CI	Controls	95% CI	*P*-value	R^2
Glucose (mmol/L)	2.83	2.66–3.00	2.79	2.65–2.94	NA[1]	0.09
Fructosamine (μmol/L)	266	258–273	252	245–258	0.17	0.14
Insulin (mU/L)	3.61	3.05–4.29	8.48	7.31–9.84	0.0002	0.42
RQUICKI[2] value	0.42	0.40–0.43	0.46	0.45–0.48	0.056	0.26
NEFA (mmol/L)	1.36	1.20–1.55	0.34	0.30–0.38	<0.0001	0.66
BHBA (mmol/L)	1.56	1.33–1.82	0.90	0.79–1.04	NA	0.29
Cholesterol (mmol/L)	3.04	2.84–3.26	3.75	3.55–3.95	0.003	0.70
AST[3] (μkat/L)	1.96	1.76–2.17	0.97	0.88–1.06	<0.0001	0.45
GD[4] (μkat/L)	197	160–243	78	65–93	0.0012	0.29
Haptoglobin (g/L)	0.76	0.60–0.97	0.17	0.13–0.20	<0.0001	0.48

[1]Not applicable because the interaction between sampling time and DA was significant for glucose ($P = 0.028$) and BHBA ($P = 0.0098$).

[2]The revised Quantitative Insulin Sensitivity Check Index.

[3]Aspartate aminotransferase; kat = unit of catalytic activity.

[4]Glutamate dehydrogenase; kat = unit of catalytic activity.

ences in serum concentrations between DA cows and controls were found during one or more of the sampling periods, although the overall interaction effect was not statistically significant.

DISCUSSION

Differences were found between cows with DA and controls in all blood parameters except glucose and fructosamine, indicating substantial alterations in metabolism. We compared DA cows with control cows sampled in the same herds and at the same time. Therefore, most of the differences in blood concentrations found in this study are likely to be acute changes associated with the DA, without confounding effects associated with management or transportation. However, because the DA was manifest at the time of sampling, it was not possible to distinguish between acute changes in blood concentrations and changes that may have been present before DA. Increases in concentration of NEFA, BHBA, and AST of the same magnitude as in our study were detected 1 to 2 wk before DA in other studies (Geishauser et al., 1997; LeBlanc et al., 2005). This implies that some of the changes may last over some time, related to other diseases foregoing the DA or to early stages in the development of DA. Left- and right-sided DA were considered together. The etiology of DA is thought to be multifactorial, but similar for displacements to different sides (Geishauser, 1995; Cameron et al., 1998; Van Winden and Kuiper, 2003). A left-sided DA can change into a right-sided DA, and vice versa (Geishauser, 1995).

There was no difference in glucose concentration between DA cows and controls, even though the DA cows were most likely in a more pronounced negative energy balance, as reflected by elevated concentrations of NEFA and BHBA. In contrast, results from several previous studies show elevated plasma concentrations of glucose in cows with DA (van Meirhaeghe et al., 1988; Muylle et al., 1990; Rehage et al., 1996; Itoh et al., 1998). All these cows were, however, transported to a clinic, which could have triggered the release of stress-related hormones such as cortisol and adrenalin, increasing blood concentrations of glucose (Holtenius and Holtenius, 1996; Kusenda et al., 2009). In our study, all cows were examined and sampled in their own herds, thus avoiding stress from transportation and changes in feed and management. Stress due to handling and the sampling procedures would have affected DA cows and controls similarly. Our results indicate that DA may not cause any consistent changes in plasma glucose concentrations. This result is supported by the findings of Stengärde and Pehrson (2002), where DA cows sampled on-farm did not have elevated glucose concentrations compared with the reference range given by the laboratory.

The cows with DA had lower concentrations of insulin compared with the control cows, most likely due to a reduced feed intake (Agenäs et al., 2003). A reduced insulin concentration further facilitates net mobilization of adipose tissue, and thus increases the hepatic uptake of fatty acids as reviewed by Hayirli (2006). Elevated NEFA concentration in plasma is a prerequisite for development of hepatic lipidosis that occurs in DA cows (Rehage et al., 1996). Insulin resistance has been suggested as part of the etiology of DA (van Meirhaeghe et al., 1988). Presently, there is no gold standard for assessing reduced insulin sensitivity in lactating dairy cows. However, RQUICKI values have been shown to be correlated with the response to

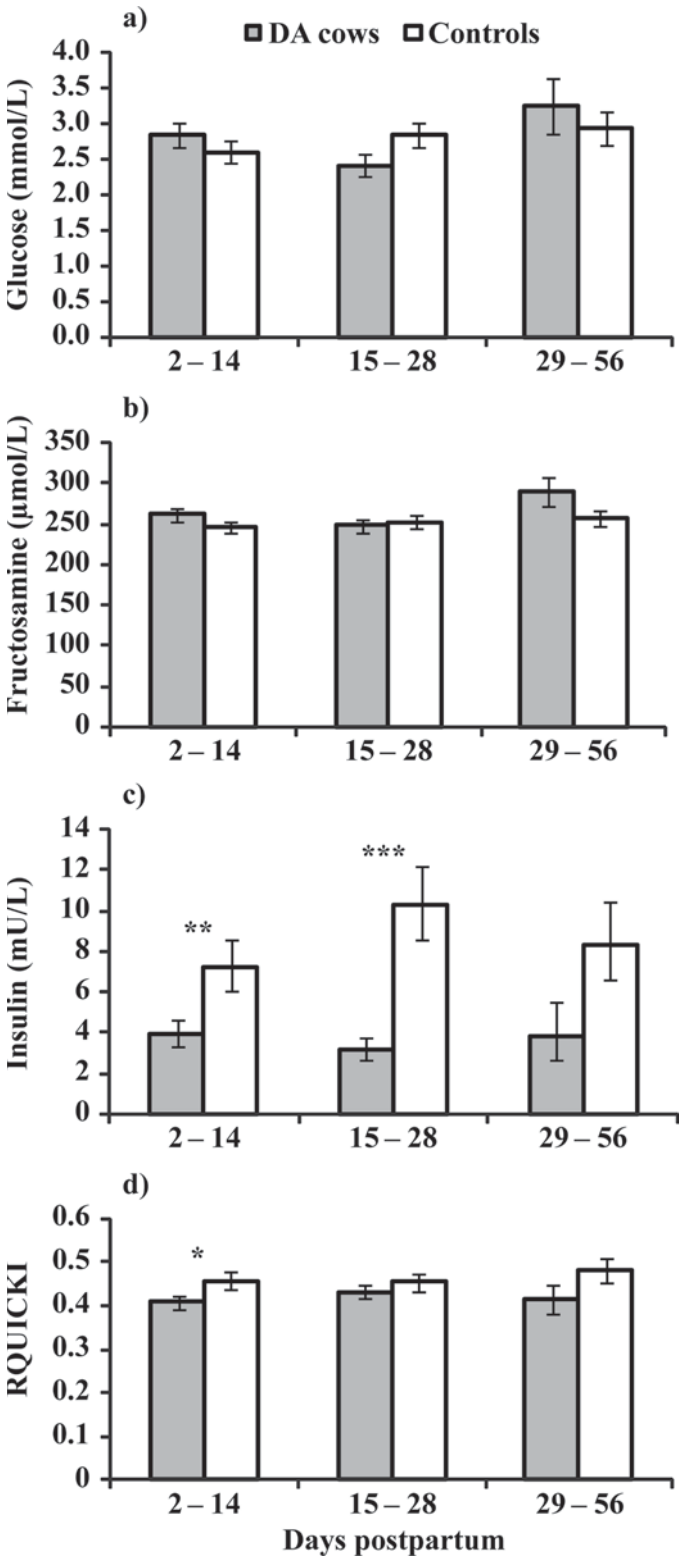

Figure 1. Least squares means with 95% confidence intervals, estimated using linear mixed models, of a) glucose, b) fructosamine, c) insulin, and d) the revised Quantitative Insulin Sensitivity Check Index (RQUICKI) value. Significant differences between cows with displaced abomasum (DA) and healthy controls within each time interval are identified (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$).

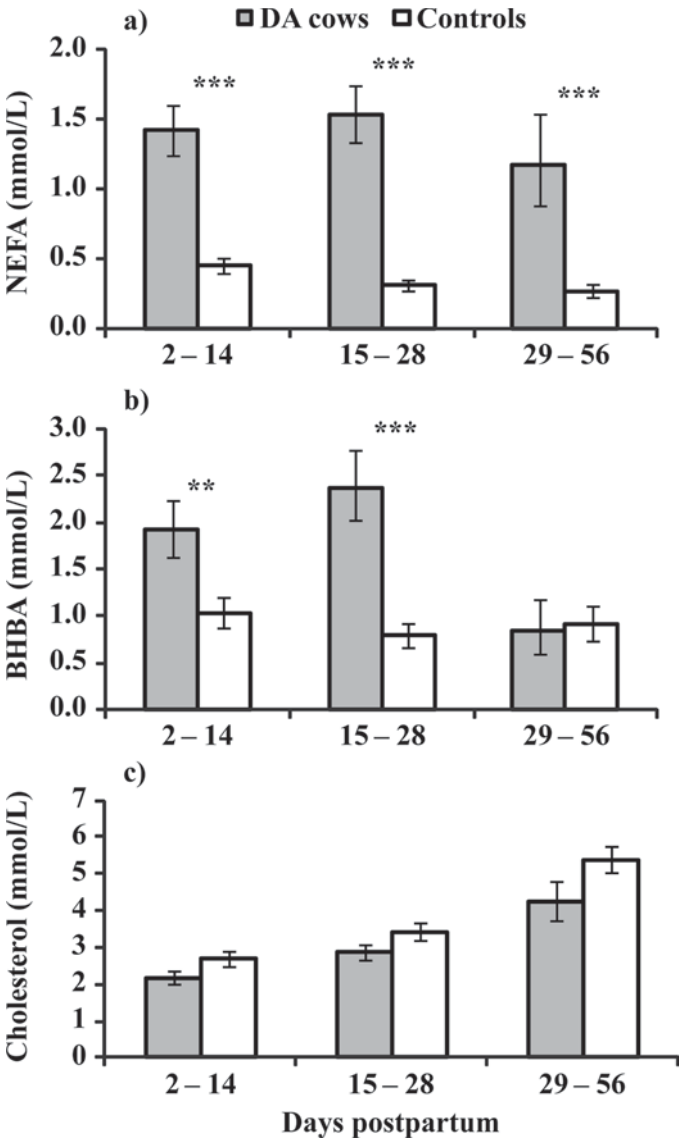

Figure 2. Least squares means with 95% confidence intervals, estimated using linear mixed models, of a) NEFA, b) BHBA, and c) cholesterol in cows with displaced abomasum (DA) and controls. Significant differences between DA cows and controls within each time interval are identified (**$P < 0.01$, ***$P < 0.001$).

an intravenous glucose tolerance test in young calves (Bossaert et al., 2009). Our analysis showed a tendency for lower RQUICKI values in DA cows compared with controls. This may imply that DA cows had reduced insulin sensitivity. However, in a study by Kerestes et al. (2009), the RQUICKI values were not correlated with insulin sensitivity in cows with ketosis and signs of puerperal metritis; consequently, the usefulness of the RQUICKI in cows with disease or reduced feed intake needs to be evaluated.

Cholesterol was lower for DA cows than for controls, which can be explained by the reduced feed intake.

Cholesterol concentrations have been shown to vary with feed intake (Janovick Guretzky et al., 2006) and with fat intake (Duske et al., 2009). Low cholesterol concentrations, however, have also been associated with hepatic lipidosis (Van den Top et al., 2005), a frequent finding in cows with DA (Rehage et al., 1996; Komatsu et al., 2002). Increased enzyme activity of AST and GD was found in the DA cows compared with the controls, indicating liver cell damage. This finding is in agreement with earlier studies of cows with DA and hepatic lipidosis (Rehage et al., 1996; Komatsu et al., 2002). Glutamate dehydrogenase was the only liver-specific parameter studied, peaking at 15 to 28 d pp, which concurs with the peak incidence of hepatic lipidosis in cows with left-sided DA, as described by Rehage et al. (1996). This suggests that the increased concentration of GD in the blood in our study may be caused by hepatic lipidosis.

In our study, elevated concentrations of haptoglobin were found in the cows with DA, which is in agreement with previous findings (Hirvonen and Pyörälä, 1998). Concentrations of haptoglobin were higher in DA cows during the entire sampling period, most likely reflecting infectious diseases or inflammatory reactions (Skinner et al., 1991; Hirvonen et al., 1999a,b), whereas control cows had low concentrations at 14 d pp. Haptoglobin could be used to detect treatable infectious or inflammatory conditions in the early postpartum period, possibly reducing the incidence of DA. The absence of association between haptoglobin concentration and other diseases may be explained by the fact that other diseases were only noted as present or not present.

The duration of symptoms was long in some of the cows, possibly reflecting difficulties in correctly diagnosing intermittent DA. Two-thirds of the cows suffered from at least one other disease before or at the same time as DA was diagnosed. The importance of other diseases in the pathogenesis of DA is supported by other studies (Rohrbach et al., 1999; Stengärde and Pehrson, 2002). The control cows were expected to be healthy, and the questionnaire therefore did not include questions about other diseases and medical treatments during the last week before sampling for this group. Recorded diseases were found retrospectively in the Swedish Official Milk Recording Scheme for some of the control cows, and these cows were excluded from the analysis.

Treatments with corticosteroids or oral infusions to increase blood glucose have the potential to alter several blood parameters. Only minor differences in blood parameters between untreated and treated DA cows were found, however, and an effect of treatment was consequently not considered in the modeling of blood parameters. One reason for not finding differences between treated and untreated DA cows, as well as between DA cows with or without concurrent disease, is the size of the study, necessitating analysis of groups of treatments or other diseases rather than individual treatments or diseases.

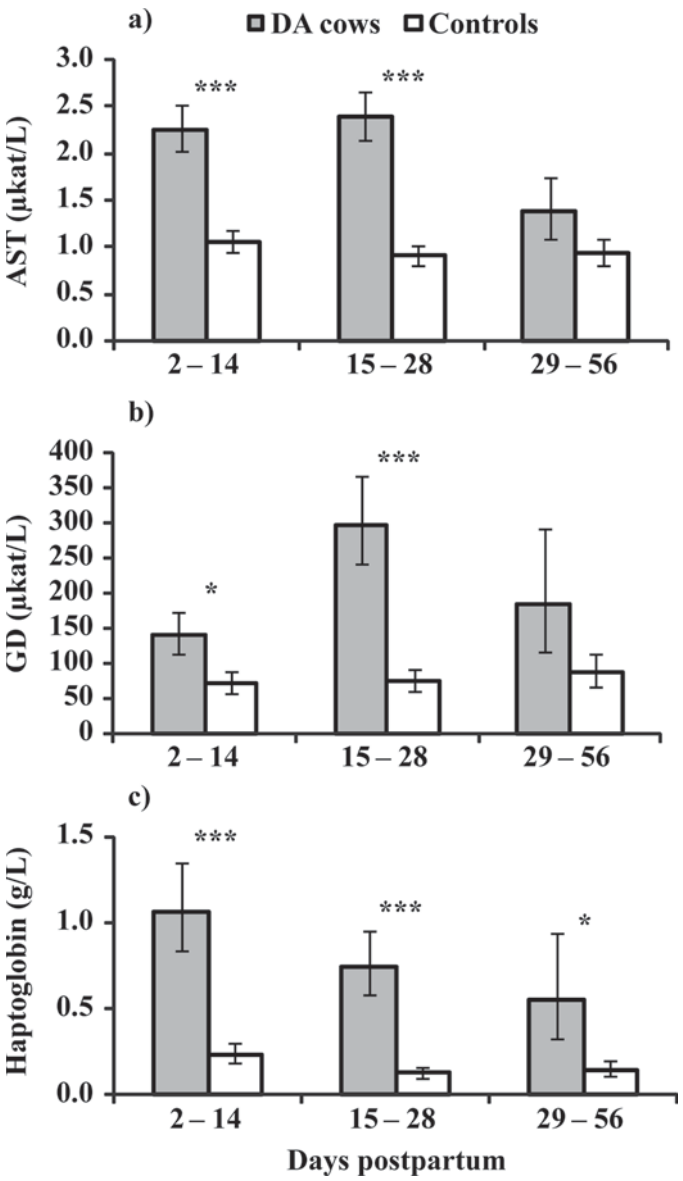

Figure 3. Least squares means with 95% confidence intervals, estimated using linear mixed models, of a) aspartate aminotransferase (AST), b) glutamate dehydrogenase (GD), and c) haptoglobin in cows with displaced abomasum (DA) and controls. Significant differences between DA cows and controls within each time interval are identified ($^*P < 0.05$, $^{***}P < 0.001$). kat = unit of catalytic activity.

For most blood parameters related to energy balance, differences between DA and control cows were similar over time. During the postpartum transition period (i.e., the first 3 to 4 wk of lactation), this may be expected because the drive to sustain lactation is similar (Herdt,

2000a). After that period, milk production is more rapidly downregulated in case of disease, and reduced feed intake and a less pronounced metabolic response can be expected. However, few cases were sampled in d 29 to 56 pp; consequently, results must be interpreted with caution for this period.

CONCLUSIONS

Major differences existed in blood profiles of cows diagnosed with DA within 2 to 56 d pp, compared with healthy control cows, indicating a negative energy balance, as well as liver cell damage and an inflammatory response.

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