Dry Cow Diet, Management, and Energy Balance as Risk Factors for Displaced Abomasum in High Producing Dairy Herds

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ABSTRACT

The objective of this study was to determine prepartum risk factors for displaced abomasum. The design was a prospective study of 1170 multiparous Holstein cows from 67 high producing dairy herds in Michigan. Each farm was visited four times within a 6-wk period. At each visit, data on nutrition and management were collected. All multiparous cows within 35 d of projected calving were assigned a body condition score, and blood was sampled to determine the concentration of nonesterified fatty acids in plasma. A multivariable linear regression model was used to determine risk factors associated with the incidence of displaced abomasum during lactation on a herd basis. A multivariable logistic regression model with random effect was used to determine risk factors for displaced abomasum on an individual cow basis. Significant risk factors for displaced abomasum included a negative energy balance prepartum (as estimated from plasma nonesterified fatty acids), a high body condition score, suboptimal feed bunk management prepartum, prepartum diets containing >1.65 Mcal of net energy for lactation/kg of dry matter, winter and summer seasons, high genetic merit, and low parity.
(**Key words**: displaced abomasum, energy balance, body condition score, plasma nonesterified fatty acids)

Abbreviation key: **BCS** = body condition score, **DA** = displaced abomasum, **IRDA** = incidence rate of DA.

INTRODUCTION

Displaced abomasum (**DA**) is a common disease in high producing dairy herds (20, 32, 33). Despite the large financial losses associated with treatment and production losses that can range from $256 to $406 per case (1), effective preventative measures have yet to be determined, which reflects the incomplete understanding of the etiologies involved.

Displaced abomasum is regarded as a multifactorial disease. Epidemiological studies have identified breed (4), sex (4), age (4, 13, 26), parturition (4, 26), and season (4, 14, 26, 32) as potential risk factors for DA. Displaced abomasum has an important association with other major periparturient diseases such as hypocalcemia (7, 23, 27, 28), ketosis (6, 11, 31, 40), and metritis (11, 26). Nutrition is considered to have a significant impact on the incidence of DA and is perhaps the most controllable factor in a dairy. However, research in this area has been sparse, and the results are controversial.

Speculation has arisen over the association between disorders of energy metabolism (hepatic lipidosis and ketosis) and the occurrence of DA (3, 6, 13, 21, 40). A negative energy balance is the initiating factor in the development of both ketosis and hepatic lipidosis, and this imbalance may frequently begin during the prepartum period (18, 19). Energy balance may be estimated from plasma NEFA concentrations, which are closely related to energy balance in ruminants (25).

An objective of this study was to identify risk factors for DA on the herd level in high producing dairy herds. Special attention was paid to prepartum diet, management, and energy balance. These results were compared with an individual cow model based on the same data file. The rationale for this two model approach was that, in practice, the herd is the unit of concern, and disease control measures are generally applied at the herd level. However, as disease affects the individual, variables specific to the individual may define risk factors for DA more clearly than variables at the herd level. Thus, variation within a herd may explain variation in herd incidence more clearly than variables between herds.

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MATERIALS AND METHODS

Selection of Farms

Herds were solicited from members of the Michigan DHIA; the current herd production of candidate herds had to be greater than the Michigan DHIA mean of 8760 kg (19,300 lb) of milk/yr per cow. Three hundred farms met this criterion of which 118 responded to a questionnaire that solicited involvement in the study. Of the 118 farms that responded, 104 farms were visited between October 27, 1993 and January 25, 1995.

Of the 104 farms visited, 67 farms were included in this study. The reasons for excluding the other 37 farms were incomplete data and inadequate cow numbers. A total of 1737 cows (465 primiparous and 1272 multiparous) were sampled from the 67 herds. After excluding primiparous cows and cows that gave birth to twins, a total of 1170 cows was included in the multivariable analysis. Primiparous cows, on the majority of farms, were housed, fed, and managed separately from multiparous cows. Therefore, we considered primipara to be a separate population that could not be grouped for analysis with the older cows on the farm. Similarly, cows giving birth to twins were excluded from the analysis because they were considered to be from a different population, metabolically, than cows carrying single fetuses. Not only are the prepartum metabolic demands of cows with twins different than those of cows with single fetuses, the distribution of abdominal contents is also likely to be different. This project was part of a larger field study (11).

Farm Visits

The responsibility of collecting and recording data on the assigned farms was delegated to four investigators among whom the 104 farms were divided. Each farm was visited four times within a 6-wk period with a minimum of 6 d between each visit.

Herd Data

During the first visit, nutrition and management data were recorded, and, during the second, third, and fourth visits, changes in nutrition or management were recorded. Feed nutrient profiles were taken from analytical records supplied by the herd owners. When no feed analysis was available, published tabular values (30) were used. Complete forage analysis data were available on 52 farms, analyses of some forages were available on 11 farms. On 4 farms, no forages had been analyzed. Feed intake on the majority of farms was difficult to estimate with accuracy. Therefore, it was assumed that the mean DMI of cows in late gestation was 10 kg/d. When the amount of concentrate fed was known, the amount of forage consumed was estimated by the difference between the DM of the concentrate and the potential DMI.

In this study, a feeding system was classified as a TMR if all dietary components were mixed together before feeding. If any dietary component was fed separately from the mixture, then the ration was not classified as a TMR. A transition diet was defined as a ration that was fed to dry cows for at least the last week of gestation and that differed in content from the ration that the cows were fed earlier in the dry period. The exact times, relative to anticipated calving, at which cows were first exposed to the transition diets were not considered in the analysis.

Feed bunk management of cows in late gestation was evaluated. A penalty score was devised for bunk management based on the combined penalty score for two factors as follows.

Bunk space. If the bunk space was <30 cm per cow or if the bunk space was 30 to 60 cm per cow and the ration was fed in limited amounts, then the bunk space score was 1. If the bunk space was >60 cm per cow or if the bunk space was 30 to 60 cm per cow and the ration was fed for ad libitum intake, then the bunk space score was 0.

Feed availability and freshness. If the bunks were not cleaned at least once a day or if feed was offered in limited amounts such that it was all consumed before the next feeding, then the feed availability and freshness score was 1. If feed was available for ad libitum intake and if the bunks were cleaned at least once a day, then the feed availability and freshness score was 0.

The penalty score for bunk space was calculated as bunk space penalty = bunk space score + feed availability and freshness score.

Cow Data

On the first and subsequent visits, all primiparous and multiparous cows in the last 5 wk of gestation were identified and assigned a body condition score (**BCS**). A blood sample from the coccygeal vessel was taken for NEFA analysis. Therefore, if cows were in the last 5 wk of gestation during more than one herd visit, BCS could have been assigned, and blood samples could have been taken, multiple times. Before the start of the field investigation, investigators standardized their scoring technique for BCS using a reference chart (Elanco Products Co., Indianapolis, IN). The BCS were assigned using a five-point scale [0.5-point increments where 1 = emaciated to 5 = severely obese; (44)].

Blood samples for the analysis of plasma NEFA were placed on ice within 15 min of collection. At the laboratory, plasma was harvested by centrifugation at 3000 rpm for 15 min. Plasma was stored at –20°C in plastic tubes. The samples were analyzed for NEFA using a commercial kit (NEFA-C kit; Wako Chemicals USA, Richmond, VA) with modifications by McCutcheon and Bauman (29), Sechen et al. (35), and Johnson and Peters (24).

Collection of Data on DA Incidence

A health sheet was left with the herdsperson at the end of the first visit to record health information on sampled cows after they had calved. From this sheet, the occurrence or nonoccurrence of DA in each cow was determined. A lactational incidence rate of DA (**IRDA**) on each farm was calculated based on cows from which NEFA and BSC values had been generated prior to calving. However, if the incidence of DA in these sampled cows was 0, postpartum health data were collected from additional cows. Data on these additional cows, on which no prepartum NEFA and BCS values were available, were collected until information on a minimum of 20 multiparous cows had been collected. This procedure was followed in 44 herds, which increased the total sample size for the herd level analysis by 623 cows (for a total of 1793), compared with the cow level analysis. This increase was advantageous because the standard error of the estimate of incidence is high when the incidence is low but diminishes as the sample size increases. Therefore, we felt it important to have as large a sample size as was practical in herds with a low incidence of DA. For all 67 farms, relative to the day of the first farm visit, all cows calved within 90 d for 85% of the farms, within 120 d for 90% of the farms, and within 150 d for 100% of the farms.

Statistical Analysis

Analysis was done at both herd and cow levels. The cow model considered risk factors for DA that were specific to the individual and used a multivariable logistic regression analysis. The herd model considered potential risk factors for DA operating at the herd level and involved a multivariable regression analysis.

The risk factors considered in the herd model are listed in Table 1. The outcome variable was the IRDA of the herd. The IRDA of each herd was calculated as IRDA = number of cows with DA/number of recorded calvings.

The risk factors considered in the cow model are listed in Table 2. The outcome variable was categorical (1 = presence of DA; 0 = absence of DA) in each

TABLE 1. Risk factors for the model based on herd and codings used in the analysis of the incidence rate of displaced abomasum.

Coding	Risk factor
0–1	Summer (if first farm visit was in June, July, or August, summer = 1; otherwise, summer = 0)
0–1	Fall (if first farm visit was in September, October, or November, fall = 1; otherwise, fall = 0)
0–1	Winter (if first farm visit was in December, January, or February, winter = 1; otherwise, winter = 0)
0–1	Spring (if first farm visit was in March, April, or May, spring = 1; otherwise, spring = 0)
1–5	Mean herd body condition score from 35 to 1 d prepartum (where 1 = emaciated to 5 = severely obese).
0–0.93	Herd incidence of NEFA concentrations >300 μeq/L in cows sampled 35 to 3 d prepartum.
9250–13,770	Mean mature equivalent, annualized milk production (kilograms) of the herd from the first visit to 150 d later.
2–4.6	Mean lactation number of cows sampled.
195–816	Mean PTA milk index (kilograms) for herd based on cows sampled.
0–1	Optimal feed bunk management (1 = no feed bunk penalty; 0 = feed bunk penality score of 1 or 2)
0 or 1	The TMR fed precalving (0 = other; 1 = yes).
0 or 1	Transition ration fed (0 = no; 1 = yes).
0 or 1	Energy density of precalving ration (≤1.65 Mcal of NE_L/kg of DM = 0; >1.65 Mcal of NE_L/kg of DM = 1).
1–5	Change in concentrate feeding before and around calving (1 = mild to 5 = severe).
1–5	Change in forage type and relative amount before and around calving (1 = mild to 5 = severe).
–5–20	Difference in nonfiber carbohydrate (percentage) between ration fed precalving and postcalving.
0–79	Percentage of dry hay in ration fed precalving.
1.21–1.61	The NE_L (megacalories per kilogram of DM) in dry cow ration.
15–46	Forage percentage of DM of NDF in ration fed to lactating cows.
16–53	Forage percentage of DM of NDF in ration fed to prepartum cows.
0–0.33	Herd incidence of milk fever based on cows sampled.

TABLE 2. Risk factors for the model based on individual cows used in analysis of the occurrence of displaced abomasum.

Coding	Risk factor
1–4	Season at time of first visit (1 = spring, March, April, and May; 2 = summer, June, July, and August; 3 = fall, September, October, and November; and 4 = winter, December, January, and February).
1–5	Mean body condition score at 35 to 1 d prepartum for individual cows (where 1 = emaciated to 5 = severely obese).
2–9	Lactation number.
–68–1259	PTA Milk index (kilograms).
0 or 1	NEFA Concentration >300 μeq/L sampled 35 to 3 d prepartum (≤300 μeq/L = 0; >300 μeq/L = 1).
0 or 1	Dystocia (0 = no; 1 = yes).
0 or 1	Milk fever (0 = no; 1 = yes).
0 or 1	Retained placenta (0 = no; 1 = yes).

cow. Table 3 shows the outcome variables for both models and their coding.

Cow Model

The computer software program used to develop the cow model was EGRET (12). A cow level multivariable logistic regression model with random effects, grouped according to herd, was used to identify risk factors associated with the occurrence of displaced abomasum. Initial variables for the starting model were selected based on biologically hypothesized relevance. Records selected for analysis did not contain any missing values for the selected variables. The reduced model was then developed from the starting model, using backward model development with a significance level of $P \leq 0.05$ for each variable in the reduction process. Model reduction stopped when all variables in the model had P values ≤ 0.05. The correlation matrices for both the initial data file and the final model were checked for potential collinearity among the independent variables using a limit of r = 0.6 ($P < 0.05$) for a correlation coefficient.

TABLE 3. Outcome variables used in analysis of displaced abomasum (DA).

Variable	Coding	Content
DA	0 or 1	DA in Observed cow (0 = no; 1 = yes)
IRDA[1]	–2.94 to –0.49	Logit-transformed IRDA (herd basis)

[1]Incidence rate of DA.

Herd Model

The risk factors were initially selected to reflect conditions that had previously been associated with the occurrence of DA. A logit transformation was performed to normalize the distribution of IRDA. The formula for the logit transformation (LT) is shown in Equation [1].

$$LT = \log \frac{IRDA + 0.05}{1 - (IRDA + 0.05)}. \quad [1]$$

The SAS (34) software was used to develop the herd model. Univariable regression models were developed for each of the risk factors. A multivariable linear regression model was developed using a backward model building procedure in which each of the remaining variables was associated ($P < 0.05$) with the outcome. Collinearity within this model was evaluated by inspecting variance inflation factors and eigenvalues using a variance inflation factor of ≥5.0 as an indicator of collinearity.

RESULTS

IRDA During Lactation

The IRDA during lactation, determined by lactation number and twin status, for all cows sampled in the study is shown in Table 4. Note that primiparous cows are included in the table but not in the modeling analyses. The 6% IRDA for primiparous cows appeared to be similar to the overall mean of 7% IRDA for multiparous cows. Among the multiparous cows, IRDA decreased from 7 and 8% for second and third parity cows, respectively, to 6 and 4% for fifth and sixth parity cows, respectively. These IRDA reflected the general decline in the IRDA as parity increased.

Analysis of Individual Cows

Table 5 shows the final multivariable model for individual cows. Of the original seven variables considered, only five remained in the final model. Significant factors in the individual cow model that were associated with an increased risk of DA included high BCS, winter season, and plasma NEFA concentration >300 μeq/L between 35 and 3 d prepartum. The risk of DA decreased as lactation number increased.

Analysis of Herd

Table 6 shows the multivariable model based on herd for the logit-transformed IRDA. No collinearity was detected in the model. Plots of residuals were

TABLE 4. Incidence of displaced abomasum (DA) according to lactation group and twin status.

Lactation	Cows	DA	
	(no.)	(no. of cases)	(%)
	All cows		
1	456	29	6
2	509	37	7
3	325	26	8
4	171	10	6
5	82	5	6
6	53	2	4
≥2	1170	80	7
	Cows with twins		
1	9	1	11
≥2	102	12	12

also generated to check for the validity of the model by the normal distribution of residuals. Of the 20 variables initially considered, only 6 remained in the condensed model. Factors associated positively ($P < 0.05$) with risk of DA in herds included PTA for milk production, BCS, winter and summer seasons, and precalving rations containing energy densities >1.65 Mcal of NE_L/kg of DM. Feed bunk management, as defined in this study, was associated negatively with the risk of DA.

DISCUSSION

The findings in this study demonstrate the importance of prepartum nutrition and management on the occurrence of DA postpartum. The significant association found between negative energy balance prepartum, as reflected by elevated NEFA concentrations, and the occurrence of DA has major practical implications for the prevention of DA. Most researchers agree that a reduction in abomasal motility is a key step in the pathogenesis of DA. The role negative energy balance plays in this causal pathway is not certain but may involve the disorders of negative energy balance, hepatic lipidosis, and ketosis.

Increased plasma NEFA concentrations in the prepartum period may cause hepatic lipidosis and ketosis (11, 18, 19, 40). One way that hepatic lipidosis might influence the IRDA is through effects on insulin. Insulin is known to reduce the rate of abomasal emptying (41), and cows with DA exhibit a resistance to insulin (8, 22, 42), which can lead to higher serum insulin concentrations. In contrast to these observations, however, Gerloff et al. (18) did not find serum insulin concentrations to be affected by the degree of hepatic lipidosis.

Ketosis (diagnosed prior to the occurrence of DA) has been implicated as a risk factor for DA in several studies (6, 13, 32, 43). Ketosis is associated with low DMI, which would reduce rumen fill and volume, reducing forestomach motility and, potentially, abomasal motility. A low rumen volume also offers less resistance to DA (4, 37).

Two other significant associations with DA in this study, higher BCS and suboptimal feed bunk management, also support the effect of negative energy balance on the occurrence of DA. Fatter cows eat less (17), have greater negative energy balance in early lactation, and have higher plasma NEFA concentrations (16). Shirley (36) reported that primiparous cows fed to a BCS of 4.0 on a five-point scale and maintained at that condition for the last 60 d before calving experienced a high incidence of subclinical ketosis and a 50% incidence of DA within the first 30 d after calving.

Optimal feed bunk management (adequate bunk space and continuously available fresh feed) would be conducive to optimal DMI and uniform consumption of feed throughout the day. Ample feed availability would allow for better nutritional status and greater rumen fill at calving, factors which may lead to a reduced incidence of DA. Forbes (15) reported that

TABLE 5. Multivariable logistic model with random effects for individual cows[1] for the occurrence or nonoccurrence of displaced abomasum.

Variable	Coefficient	P	Risk ratio	95% CI[2]
Overall mean	–5.694	0.001	0.0034	0.0005–0.0228
Body condition score	0.8777	0.001	2.405	1.41–4.10
Winter season	1.087	0.002	2.967	1.48–5.96
Elevated NEFA	0.7139	0.007	2.042	1.22–3.42
Lactation number	–0.2138	0.045	0.8075	0.66–1.0

[1]Overall model deviance with 1077 df = 519.530. Likelihood ratio statistic for random effects term = 10.9 ($P < 0.283$).

[2]Confidence interval.

TABLE 6. Multivariable linear regression model for analysis by herd[1] using logit-transformed incidence of displaced abomasum.

Variable	Coefficient	F	P
Intercept	–5.30	25.06	0.0001
PTA Milk	0.0006	7.27	0.0091
Optimal bunk management	–0.343	4.69	0.0343
Summer season	0.339	4.67	0.0347
Winter season	0.632	10.28	0.0022
NE_L >1.65 Mcal of NE_L/kg of DM	0.388	4.13	0.0465
Body condition score	0.650	5.21	0.0260

[1]Model $R^2 = 0.344$; $F = 5.25$ with 66 df ($P < 0.002$).

cows exhibited a decline in DMI in the final days of gestation. In ewes, as pregnancy advances, meal size decreases, and meal frequency increases (2). This change in feeding behavior might be a consequence of decreased rumen capacity as the uterus enlarges. If this change in feeding behavior is also true in cows, then one might expect the availability of fresh feed throughout the day to increase DMI.

In this study, prepartum diets containing >1.65 Mcal of NE_L/kg of DM were associated with an increased risk of DA. Such rations that are rich in energy density reflect a high level of concentrate feeding. A possible explanation for the association may be that cows fed a high concentrate diet compared with cows fed a low concentrate diet have a greater decline in DMI before calving as has been observed in some studies (5), but not in others (38). A possible reason for this decline may be dietary selection. Evidence suggests that estrogen, which increases in the final days of gestation, affects dietary selection in ruminants, causing a reduction in concentrate intake but not in forage intake (15). Thus, a preference for forage might result in a lower intake of rations that are high in concentrate and a benefit of rations that are high in forage. Decreased DMI compounded by a low forage component might have resulted in a reduced rumen volume postcalving. As discussed, a small rumen volume offers less resistance to DA (4, 37). A high level of concentrate feeding might also cause rumen acidosis and decreased appetite, especially if the energy density of the ration changed suddenly.

Prepartum diets containing >1.65 Mcal of NE_L/kg of DM may indicate that cows were being overfed energy in the dry period. Cows on a very high plane of nutrition throughout the dry period may become obese. Such cows have been shown to have a greater degree of negative energy balance in early lactation, possibly as a result of lower DMI (15). High plasma NEFA concentrations postpartum in these cows can result in hepatic lipidosis (39).

No other significant associations between diet and the IRDA were found in this investigation. In comparison, no association with dietary factors was found in studies by Dohoo et al. (10) and Martin (27). The lack of further dietary associations in this study might have been due to inaccuracies in the comparison of diets. The difficulty of estimating DMI in field investigations makes comparisons between herds, with respect to diet, potentially inaccurate.

Winter (December, January, and February) in the cow model and winter and summer (June, July, and August) in the herd model were associated with an increased IRDA. Similar findings of a seasonal association with IRDA have been reported (4, 33). Although no theory to explain this association has been proven, negative energy balance may be involved. High environmental temperatures reduce DMI in summer (45). In winter, cold temperatures increase the energy requirements of cows. Any factor (management, dietary, or environmental) that reduces energy intake in late gestation may have an even more profound effect in winter when maintenance energy requirements are increased.

Although herds with high mean PTA milk were associated with a higher IRDA, cows with high PTA milk within herds were not more likely to experience DA. Herd PTA milk is influenced by breeding management, and the occurrence of DA might have been associated with some correlated aspects of management that were undefined in this study. If, in contrast, cows with greater milking ability are more likely to experience DA, then the apparent increased incidence of DA in the last 40 yr may be partly a result of changes in genetics.

As lactation number increased, IRDA decreased. Other field studies have reported an opposite trend (26, 27) or an inconsistent trend (9). A recent report (31) citing a higher IRDA in primiparous cows versus older parity cows is consistent with our finding of reduced risk as age advanced.

The two modeling approaches, one based on the individual cow and the other based on herd, that were used in the analyses of these data yielded complementary results. The impact of optimal bunk management, herd mean PTA milk, prepartum rations containing >1.65 Mcal of NE_L/kg of DM, and summer season on IRDA would have been overlooked if only the cow model had been studied. Similarly, the importance of negative energy balance, as assessed by plasma NEFA concentration, to IRDA would have been overlooked if only the herd model had been evaluated. The combined findings of these two models appear to reinforce each other, concluding that negative energy balance increases the risk of DA.

CONCLUSIONS

Significant risk factors for DA included high plasma NEFA concentrations prepartum, high BCS, suboptimal feed bunk management, prepartum diets containing >1.65 Mcal of NE_L/kg of DM, winter and summer seasons, high genetic merit, and low parity. The results of this study support the theory that hepatic lipidosis may be an important risk factor for DA (3, 21). The significance of suboptimal feed bunk management and overconditioning further supports this theory. Herds with high mean PTA milk were associated with a high occurrence of DA. This association is a new finding, worthy of further investigation because if this association is significant, the trend for continued increases in the IRDA is likely to continue with improving dairy cow genetics.

Practical Recommendations

Herd IRDA is likely to be reduced by avoiding a negative energy balance prepartum, by avoiding overconditioning, and by providing optimal feed bunk management to cows in late gestation. A seasonal calving pattern to avoid the higher risk periods of the year may not be feasible on many farms. However, an effort could be made to avoid calving cows in the hot summer months when it is known that DMI can be significantly reduced.

The importance of ensuring optimal nutrition is highlighted in both models. Bunk management that ensures that cows have adequate access to fresh feed at all times should maximize DMI in late pregnancy and thus improve energy balance. A prepartum diet containing more nutrients than recommended by the NRC (30) may be a feasible way of improving the nutritional status of peripartum cows as has been reported by VandeHaar et al. (38). However, based on the present results, energy density should not be >1.65 Mcal of NE_L/kg of DM.

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