Effect of Birthweight, Total Protein, Serum IgG and Packed Cell Volume on Risk of Neonatal Diarrhea in Calves on Two California Dairies

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ABSTRACT

The objective of the study was to determine if there was a relationship between hematological, immunological and physiological variables of newborn calves and risk of diarrhea during the neonatal period. Four hundred and seventeen heifer calves from two dairies (A and B) in the San Joaquin Valley of California were enrolled at birth and scored daily, to 28 days of age, for evidence and severity of diarrhea (0 to 3). Calves were weighed at birth and blood sampled at two to five days of age to determine packed cell volume (PCV), total protein (TP) and IgG serum concentration. The Cox proportional hazards model was used to determine if age at onset of the first diarrhea episode and length of the first episode were associated with the hypothesized variables (PCV, TP, IgG and birthweight). The IgG concentration was not associated with the age at onset of diarrhea (p = 0.6052, Dairy A; p = 0.4393, Dairy B) but a high IgG concentration was associated with a decreased length of episode (p = 0.0325, Dairy A; p = 0.0912, Dairy B), particularly for calves born in the winter on dairy A (p = 0.0211). For calves born in the winter, those with either a high or a low birthweight had diarrhea at a younger age (p = 0.0102, Dairy A; p = 0.0020, Dairy B). Associations were also found for PCV and TP with both the age at onset and length of the first episode of diarrhea. Results suggest that parameters measurable at, or shortly after birth may have important prognostic value in evaluating risk of calf diarrhea.

RÉSUMÉ

L'objectif de cette étude était de déterminer s'il y avait des relations entre des variables hématologiques, immunologiques et physiologiques de veaux nouveau-nés et le risque de diarrhée en période néonatale. Quatre cent dix-sept génisses de deux fermes laitières (A et B) de la Vallée San Joaquin en Californie ont été enregistrées à la naissance et évaluées quotidiennement pendant 28 jours pour la présence et la sévérité de diarrhée (0 à 3). Les veaux étaient pesés à la naissance et un échantillon sanguin prélevé entre deux et cinq jours d'âge afin de déterminer l'hématocrite (HT), les protéines totales (PT) et la concentration sérique d'immunoglobulines (IgG). Le modèle de survie de Cox a été utilisé afin de déterminer si l'âge au début du premier épisode de diarrhée et la durée de cet épisode étaient associés avec les variables HT, PT, IgG et le poids à la naissance. La concentration d'IgG n'était pas associée avec l'âge au début de l'épisode de diarrhée (p = 0.6052, Ferme A; p = 0.4393, Ferme B). Une concentration élevée d'IgG était associée avec une réduction de la durée de l'épisode (p = 0.0325, Ferme A; p = 0.0912, Ferme B), surtout pour les veaux nés en hiver sur la Ferme A (p = 0.0211). Durant l'hiver, les veaux lourds ou légers à la naissance ont eu leur premier épisode de diarrhée plus tôt (p = 0.0102, Ferme A; p = 0.0020, Ferme B). Des associations entre HT et PT, et l'âge au début ainsi que la durée du premier épisode de diarrhée ont été identifiées. Les résultats suggèrent que certains paramètres mesurés durant la période périnatale peuvent être d'importants facteurs lors de l'évaluation du risque de diarrhée chez les veaux.

INTRODUCTION

Neonatal calf diarrhea is a common and costly problem in dairy herds (1,2). Although most of the agents implicated as causes of diarrhea (3) are commonly found on dairies, the incidence of clinical diarrhea appears to vary markedly among dairies (4). One explanation for this could be that factors that cause variation in morbidity within a herd are distributed differently among herds, and that factors other than infectious disease agents may contribute to the variation. Calving, feeding, vaccination, housing and colostrum management, have been considered to be possible predisposing factors for neonatal diarrhea on some dairies (5,6,7,8,9,10).

There are a number of parameters that are known, or proposed, to be useful in measuring a calf's predisposition to morbidity or mortality. Serum IgG concentration is well documented as an important factor in calf health (7,9,11,12,13,14,15,16,17). Other physiological measures that have been suggested to influence a calf's risk of morbidity or mortality include high and low birthweight (BWT) (13,18,19), total protein (TP) and packed cell volume (PCV) (20,21,22) at or shortly after birth. Little is known, however, about how these variables affect the risk of diarrhea. Knowledge of the extent to

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Funded in part by a cooperative agreement with USDA/APHIS/VS, USDA Formula Funds, and by the Livestock Disease Research Laboratory, University of California, Davis.

Submitted February 10, 1993.

which these variables might be associated with diarrhea would be useful in developing preventive measures and in assessing the prognosis of individual cases.

The objective of this study was to determine if an association existed between PCV, TP, IgG and birthweight of newborn heifers and the subsequent age at onset and duration of the first episode of neonatal diarrhea.

MATERIALS AND METHODS

STUDY POPULATION

Calves were born and raised on two dairies (Dairy A and Dairy B) in the San Joaquin Valley of California between January 1991 and July 1992. Every third heifer calf born between January 1991 and January 1992 on dairy A was enrolled, and every heifer calf born on dairy B between July 1991 and July 1992 was enrolled. Calves were followed from birth through the neonatal period (28 days).

Herd A is a commercial herd milking 1800 Holstein cows. Cows were vaccinated for infectious bovine rhinotracheitis virus (IBRV), parainfluenza 3 virus (PI3V), bovine viral diarrhea virus (BVDV) (live) (Bovishield 3, Norden) and leptospira (Lepto 5, AgriLab) at 14 months of age. Most calves were born in either a cow or a heifer group calving pen. Calves were bottle-fed twice 2 L of pooled colostrum of quality unknown, at an average of 3.25 hours and 13.5 hours of age. Calves were fed twice daily 2 L of whole milk in buckets until two to three weeks of age, after which 3 L of milk replacer and hospital milk (50:50) was fed twice daily until weaned at 10 weeks of age. Grain was available ad libitum from 2.5 weeks of age, and 4 L of water was available twice daily in the summer only. Calves were housed in wooden hutches with a dirt floor in the summer and straw bedding in the winter. Treatment of diarrheic calves consisted of oral electrolytes (Vitamins and Electrolytes "Plus", AgriLab), oral antibiotics (Stockade Calf Formula Plus, Kern Livestock Supplement, 13 g/kg neomycin sulfate and 6.5 g/kg oxytetracycline, dosage: 1 tablespoon and SMZ, Sidmac Laboratories, trimethoprim 80 mg and sulfamethoxazole 400 mg, dosage 2 tablets) and withholding milk for one feeding. Severe cases were treated with injectable antibiotics (Gentamicin, Elkins Sinn Inc, gentamicin sulfate 40 mg/dL, dosage 3 mL IM).

Herd B is a purebred herd of 200 milking Holstein cows. Cows were vaccinated for IBRV, PI3V, BVDV, bovine respiratory syncytial virus (BRSV) (live) and leptospira (Jencine IBPL5, Coopers) one month before breeding. J5 vaccine (Poultry Health Laboratories) was administered to dry cows 60 and 30 days prior to calving. Most calves were born in a group calving pen. Monoclonal K99 (Scourcheque E. coli 99 antiserum, RXV) oral antibodies were given to all calves at birth. Calves were bottle-fed twice 2 L of the dam's first milking colostrum at an average of 1.25 hours and 11.25 hours of age. Calves were bottle-fed twice daily 2 L of whole milk until six weeks of age, after which 3 to 4 L of milk replacer and milk (50:50) were fed in buckets twice daily until weaned at 16 weeks of age. Grain and hay were available ad libitum after five days of age, water was year-round. Calves were housed for the first two weeks of life in wooden hutches with sand floor, and with rice hull and wood chip bedding thereafter. Treatment of diarrheic calves consisted of oral electrolytes (Biolyte, Upjohn) administered four to five times a day. After March 1992, injectable antibiotics (Pen Aqueous, RXV, 300,000 IU/mL,dosage: 5 mL s.i.d. 3 days) were administered and milk was withheld from calves for a day.

DATA COLLECTED AND DIARRHEA VARIABLES

Calves were weighed at birth and a sample of whole, and EDTA blood was collected from the jugular vein between day 2 and day 5 of age. Consistency of feces was scored subjectively each day by a technician trained and supervised by a veterinarian. An ordinal scale of 0 to 3 was used, where a score of 0 indicated no diarrhea and a score of 3 indicated profuse watery diarrhea. Scores were validated by a veterinarian on randomly selected calves. A calf was considered to have had an episode of diarrhea if its fecal score was not zero. Duration of diarrhea was defined as the number of consecutive days of diarrhea, where episodes were delimited by at least two days of a fecal score of zero. Treatments administered by the calf feeder, and dates of death or euthanasia were recorded daily.

HEMATOLOGICAL AND IMMUNOLOGICAL MEASUREMENTS

Packed cell volume (PCV) was estimated using microcapillary tubes and a centrifuge. Total protein (TP) was estimated using a refractometer. Initially, sera were frozen at $-70°C$, and later serum immunoglobulin G (IgG) concentration was measured by radial immunodiffusion, using a commercially-available kit (RID kit for the quantitative determination of bovine immunoglobulin G (regular and low level), ICN Biomedicals, Inc., Costa Mesa, California).

STATISTICAL ANALYSIS

Actuarial life tables were used to describe distributions of first diarrhea episodes during the neonatal period. Student's *t*-tests were used to determine differences in TP, PCV, IgG and birthweights between dairies and among calves born in different seasons.

The Cox proportional hazards model was used to determine if the age at onset of diarrhea and the length of the first episode were associated with PCV, TP, IgG and birthweight (Table I). The PCV was subjected to an arcsine square root transformation for normalization purposes. Packed cell volume was also included as the absolute value of the difference from the median PCV of calves on the dairy (MPCV). The transformation was intended to measure any effect due to either high or low PCV. Total protein and birthweight were transformed in a similar fashion, as the deviation from the median (MTP and MBWT). Seasons of birth were included as possible confounders by use of three dummy variables (WINTER, SUMMER, SPRING), with the reference being FALL. All two-factor interaction terms were included. Covariates were included in the models as possible confounders, to retain main-effect terms, or for comparison purposes between herds.

Two models (I and II) were constructed for each dairy. In model I, the relationship between the age at onset of the first episode of neonatal diarrhea and the following variables was examined: PCV, TP, birthweight (as measured and as deviations from median), IgG, and season of birth. In model II, the outcome of interest was the duration of the first episode of diarrhea during the neonatal period. Age at beginning of the episode, severity on day 1 of the episode and three time-dependent covariates were included in addition to the variables used in model I. The time-dependent covariates were severity on days 2 and 3 of the episode and the day of the episode the calf was first treated. The corresponding two-factor interaction terms were included.

The 3D, 1L and 2L programs of the statistical package BMDP (23) were used for all statistical computations. The final models and coefficient estimates were obtained by using forward- and backward-selection procedures. The p-values of 0.10 for dairy A, and 0.15 for dairy B were considered as significant, given the sample sizes.

TABLE I. Covariates used in Cox proportional hazard models for age at onset and for duration of first episode of diarrhea in calves from two dairies in the San Joaquin Valley of California

Code	Description	Model[a]
LIGG	Logarithm of IgG (mg/dL)	I,II
PCV	Packed cell volume (%)	
ASPCV	Arcsine square root of PCV	I,II
TP	Total protein (g/dL)	I,II
BWT	Birthweight (kg)	I,II
MBWT	Absolute value of (BWT-median(BWT))	I,II
MPCV	Absolute value of (PCV-median(PCV))	I,II
MTP	Absolute value of (TP-median(TP))	I,II
WINTER	Equals 1 if calf born between 12/21 and 03/20; 0 if not	I,II
SPRING	Equals 1 if calf born between 03/21 and 06/20; 0 if not	I,II
SUMMER	Equals 1 if calf born between 06/21 and 09/20; 0 if not	I,II
FALL	Reference season	
AGEBEG	Age at first onset (days)	I,II
LENGTH	Duration of first episode (days)	II
SEV1	Severity on day 1 of episode (0–3)	II
ZSEV2	Severity on day 2 of episode (0–3) (Time-dependent covariate)	II
ZSEV3	Severity on day 3 of episode (0–3) (Time-dependent covariate)	II
ZTREAT	Day of episode calf was first treated (Time-dependent covariate)	II

[a]Model: I = age at onset of the first episode of diarrhea
II = duration of the first episode of diarrhea

TABLE II. Descriptive statistics for packed cell volume (PCV), total protein (TP), serum IgG concentration and birthweight (BWT) of newborn heifers on two dairies in the San Joaquin Valley of California

Variable	Measure	Dairy A (n = 325)	Dairy B (n = 92)
PCV (%)[a]	Mean	33.2	31.2
	Median	33.0	31.0
	Range	17-53	17-48
	SD	6.2	6.1
TP (g/dL)[b]	Mean	6.82	6.50
	Median	6.80	6.50
	Range	5.0–10.9	4.9–9.2
	SD	0.78	0.77
IgG (mg/dL)[c]	Mean	1882	1558
	Median	2000	2000
	Range	17–6941	2–5656
	SD	2	3
BWT (kg)	Mean	41.3	41.6
	Median	40.8	43.1
	Range	29–68	29–50
	SD	10.2	9.1

[a]Student's *t*-test indicated a significant difference between means for the two herds ($p = 0.0067$)
[b]Student's *t*-test indicated a significant difference between means for the two herds ($p = 0.0007$)
[c]Descriptive statistics on IgG were computed using the logarithmic transformation of IgG

RESULTS

A total of 417 calves was enrolled, 325 on dairy A and 92 on dairy B. The cumulative mortalities during the neonatal period were 6.7% and 12.8% for dairy A and B, respectively. Descriptive statistics of the variables measured at birth are presented in Table II. On dairy A, the mean TP and IgG concentrations were significantly higher in calves born in the fall (TP = 7.07 g/dL, IgG = 2245 mg/dL) than in those born during winter (TP = 6.57 g/dL, IgG = 1860 mg/dL; $p < 0.0001$ and $p = 0.0307$, respectively) and spring (TP = 6.72 g/dL, IgG = 1483 mg/dL; $p = 0.0103$ and $p = 0.0025$, respectively). The mean TP was significantly higher ($p = 0.0090$) in calves born in the summer (TP = 6.84 g/dL) than in those born in the winter (TP = 6.57 g/dL). On dairy B, the mean birthweight was significantly higher in calves born in the winter (BWT = 43 kg) than in those born during spring (BWT = 40 kg; $p < 0.0001$) and summer (BWT = 40 kg; $p = 0.0066$).

For both dairies, the mean and median age at time of blood sampling were 64 and 48 hours, respectively. The proportion of calves having failure of passive transfer, where the serum IgG concentration was less than 1000 mg/dL (7), was 9.2% for dairy A and 13.0% for dairy B. The coefficient of determination (R^2), estimated by linear regression, between TP and LIGG was 0.43 ($p < 0.00005$) and 0.58 ($p < 0.0005$) on dairies A and B, respectively.

The number of calves that had at least one episode of diarrhea during the neonatal period was 272 (83.7%) for dairy A and 54 (58.7%) for dairy B. Figure 1 illustrates the daily risk of diarrhea throughout the neonatal period for each dairy, as estimated by the actuarial life table method. The average age at onset of diarrhea was 10.4 days for dairy A and 9.3 days for dairy B. The average duration of the first episodes of diarrhea was 3.9 days and 4.1 for dairies A and B, respectively. The proportion of calves

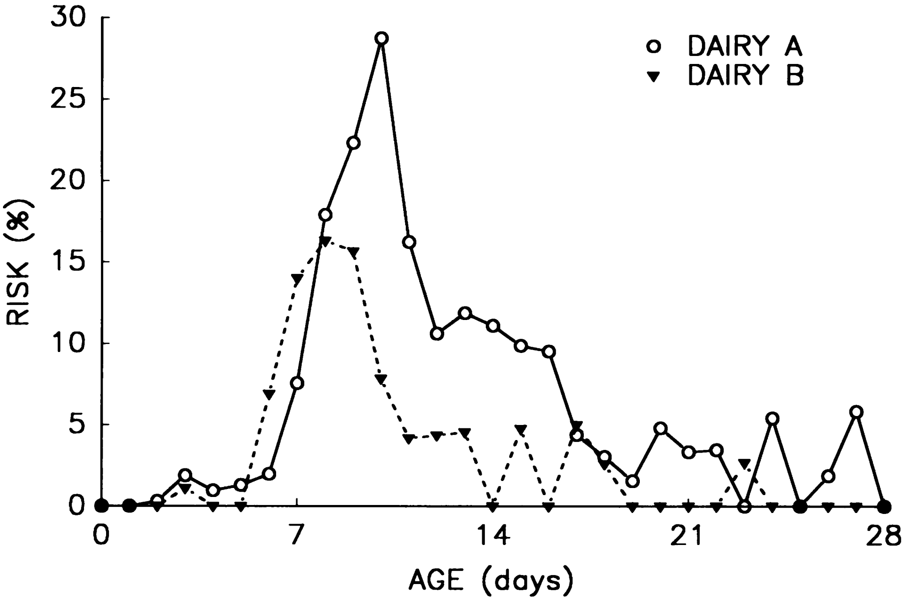

Fig. 1. Age-specific risk of the onset of calf diarrhea for the neonatal period on two dairies (A, n = 325; B, n = 92) in the San Joaquin Valley, California.

TABLE III. Model I: Cox proportional hazard model of age at onset of the first episode of neonatal diarrhea in calves on two dairies in the San Joaquin Valley of California

Variable	Coefficient	z-score[a]	p value
Dairy A (n = 325)			
WINTER[c]	−0.8569	−3.1918	0.0014
SPRING[c]	−0.0317	−0.1797	0.8574
SUMMER[c]	0.4277	2.5705	0.0102
BWT	−0.0188	−1.3501	0.1770
LIGG	−0.0996	−0.5169	0.6052
MBWT	−0.0217	−0.9122	0.3617
ASPCV	1.1130	1.1340	0.2567
MPCV	−0.0200	−1.1558	0.2478
MTP	0.3003	1.9154	0.0554[b]
WINTER*MBWT	0.1325	2.5679	0.0102[b]
Dairy B (n = 92)			
WINTER[c]	−9.2783	−2.2597	0.0238
SPRING[c]	0.1743	0.3481	0.7278
SUMMER[c]	1.5325	3.3462	0.0008
BWT	−0.0446	−0.7156	0.4743
LIGG	0.2202	0.7732	0.4393
MBWT	−0.0022	−0.0282	0.9774
ASPCV	−4.1435	−1.6368	0.1017[b]
MPCV	−0.0220	−0.4770	0.6334
MTP	0.4460	1.4106	0.1584
WINTER*ASPCV	16.5633	2.4553	0.0140[b]
WINTER*MPCV	−0.2793	−1.8315	0.0670[b]
WINTER*MBWT	1.1962	3.0802	0.0020[b]

[a]z-score = coefficient/standard error
[b]Coefficients significant ($p \leq 0.10$, Dairy A; $p \leq 0.15$, Dairy B)
[c]Seasons were entered as possible confounders

treated during their first episode of neonatal diarrhea was 73% on dairy A and 91% on dairy B. The mean time of treatment after onset of the first episode was 1.5 days on dairy A and 1.2 days on dairy B.

MODEL I

Model I examined the age at onset of the first episode of diarrhea. The coefficients, z-scores and corresponding p-values for the variables included in the model for each dairy are presented in Table III.

On both dairies, IgG concentration was not associated with age at onset of diarrhea (p = 0.6052, Dairy A; p = 0.4393, Dairy B). An interaction between the difference from the median birthweight (MBWT) and winter was associated with an increased risk of diarrhea (p = 0.0102, Dairy A; p = 0.0020, Dairy B), such that either a high or low birthweight was associated with an earlier age at onset for calves born during the winter. Either high or low total protein at birth was associated with an onset of diarrhea at an earlier age for calves on dairy A (p = 0.0554), but only marginally for calves on dairy B (p = 0.1584). On dairy B, high values of PCV were associated with a decreased risk of diarrhea (p = 0.1017). An interaction between winter and PCV (p = 0.0140) was associated with an earlier age at onset, while an interaction between winter and the deviance from the median PCV (MPCV) was associated with a decreased risk of diarrhea. While these results are contradictory, it seems that for calves born in the winter on dairy B, either low or high PCV were associated with an increased risk of diarrhea.

MODEL II

Model II examined the duration of the first episode of diarrhea. The coefficients, z-scores and corresponding p-values for the variables included in the model for each dairy are presented in Table IV.

On both dairies, high IgG levels were associated with a shorter duration of diarrhea (p = 0.0325, Dairy A; p = 0.0912, Dairy B). On dairy A, an interaction between IgG level and severity on day 2 of an episode (p = 0.0802) was associated with an increased duration of an episode, while an interaction between IgG level and winter (p = 0.0211) was associated with a decreased duration of an episode. These interactions suggest that calves with a high IgG concentration (2000 mg/dL) were more likely to have a shorter episode than calves with a low IgG concentration (500 mg/dL); this was significant only for calves born in winter and with a low severity score (1) for day 2 of the episode. For dairy B, high PCV was associated with an increased duration of first episode (p = 0.0230). For dairy A, an interaction term between PCV and winter (p = 0.0812) suggested that only calves born in winter with high PCV had shorter episodes.

Severe diarrhea on day 2 of an episode for calves on dairy A (p =

0.0114) and possibly on day 3 for calves on both dairies (p = 0.1035, Dairy A; p = 0.1586, Dairy B) were associated with an increased duration of diarrhea. Two-factor interaction terms involving the time-dependent covariate for treatment time (ZTREAT) were not evaluated on dairy B because a high proportion of calves were treated (91%). Treated calves experienced an increased duration of diarrhea episode on dairy B (p = 0.0272). An interaction between treatment and severity on day 1 of an episode on dairy A was associated with a decreased duration of an episode (p = 0.0888), such that calves with a severe diarrhea on the first day of the episode and treated early had shorter episodes. Older age at onset was associated, on dairy A, with shorter episodes of diarrhea (p = 0.0008).

TABLE IV. Model II: Cox proportional hazard model of duration of the first episode of neonatal diarrhea in calves on two dairies in the San Joaquin Valley of California

Variable	Coefficient	z-score[a]	p value
Dairy A (n = 272)			
WINTER[c]	−8.7349	−2.7019	0.0070
SPRING[c]	0.2201	1.1805	0.2378
SUMMER[c]	0.1959	1.1301	0.2584
BWT	0.0164	1.2291	0.2189
LIGG	0.9501	2.1393	0.0325[b]
ASPCV	−0.4764	−0.4101	0.6818
AGEBEG	0.0576	3.3727	0.0008[b]
SEV1	−0.3570	−1.1314	0.2578
ZSEV2	−0.2636	−2.5293	0.0114[b]
ZSEV3	−0.2171	−1.6286	0.1035
ZTREAT	−0.3865	−1.7364	0.0824[b]
WINTER*ASPCV	4.4553	1.7436	0.0812[b]
WINTER*LIGG	1.9096	2.3048	0.0211[b]
SEV1*ZTREAT	0.5653	1.7020	0.0888[b]
ZSEV2*LIGG	−0.4391	−1.7497	0.0802[b]
Dairy B (n = 54)			
WINTER[c]	1.2727	1.7920	0.0731[b]
SPRING[c]	0.0180	0.0264	0.9789
SUMMER[c]	0.2989	0.4786	0.6322
BWT	0.0425	0.8493	0.3958
LIGG	1.0033	1.6890	0.0912[b]
ASPCV	−7.9983	−2.2727	0.0230[b]
AGEBEG	0.0630	1.2054	0.2280
SEV1	0.0513	0.1263	0.8995
ZSEV2	−0.6349	−1.2900	0.1970
ZSEV3	−0.5580	−1.4101	0.1586
ZTREAT	−1.8579	−2.2099	0.0272[b]

[a] z-score = coefficient/standard error
[b] Coefficients significant ($p \leq 0.10$, Dairy A; $p \leq 0.15$, Dairy B)
[c] Seasons were entered as possible confounders

DISCUSSION

An important finding in this study was the lack of association between IgG serum concentration and the age at onset of the first episode of diarrhea. Newborn IgG level is known to influence survival in calves, but the relationship with morbidity is unclear (7,9,11–17). Our results suggest that IgG concentration may not necessarily be a risk factor for age at onset of diarrhea if a high quality of colostrum management is practiced, as indicated by the low frequency of passive transfer failure on both dairies studied. In herds where most calves have high IgG concentrations, risk of diarrhea may be attributable to other exposures or innate factors of the calf.

Results from this study suggest that high levels of IgG decreased the length of an episode of diarrhea, more so in calves born in winter months than those not. The leakage of immunoglobulins into the bowel that occurs during inflammatory changes may explain this association (9,24). A high microbial challenge expected during warmer months may contribute to a decreased efficiency of high IgG levels in reducing the length of an episode. A similar explanation may exist for the observation that as the severity of diarrhea increased, the beneficial effect of high IgG levels in shortening the episode decreased.

The age at onset of diarrhea was lower in lighter and in heavier newborn calves on both dairies, for calves born in the winter. Lighter calves may have been premature and unable to suckle adequately (25), while larger calves may have experienced dystocia and associated immunosuppression (9,26). It has been suggested that winter conditions can compromise calf health (27). Lighter calves may experience an additional risk because they have a greater body surface area in relation to their body mass, which would allow heat to dissipate and increase their energy requirements in winter months (28).

Another relationship observed which may have practical importance in prevention of diarrhea was that high and low TP and PCV values were found to be associated with age at onset and length of the first episode of diarrhea. Different factors may affect the TP and PCV values of a newborn calf. Total protein and PCV have been reported to be lower in the first week of life due to the expansion of plasmatic fluids following ingestion of colostrum (21,22,29,30). High PCV and TP usually indicate dehydration, which may be caused by a decrease of fluid intake and excessive fluid loss, perhaps as a result of disease (31,32). Hypoproteinemia can be attributable to failure of passive transfer, dam or calf malnutrition, or to blood loss (32), while low PCV is found with blood loss or anemia (21). The presence of interaction terms, and the limited sample size on dairy B did not allow us to specifically identify the nature of the relationship between these parameters and risk of diarrhea. Results did suggest that the fluid balance of the newborn calf does have an impact on neonatal diarrhea and that inadequate hydration of the newborn calf may be a factor worth considering in efforts to reduce diarrhea. Further studies are necessary to determine if similar relationships exist for calves of other dairies and to further understand the physiological nature of such relationships.

The results of this study suggest that the severity scores on the first three days of the first episode of neonatal diarrhea can be important predictors of the duration of that episode. An explanation may be that the damage to the gut in more severe diarrhea episodes may increase the time to recovery of these calves. On dairy B, the association between treatment and duration of the episode was considered as a bias since almost all calves (91%) were treated and only 5/92 were not, reducing considerably the sample size.

We conclude that parameters that can be measured at, or shortly after birth, such as PCV, TP, IgG and birthweight, may provide important prognostic information on neonatal diarrhea in dairy calves, which may be useful in reducing risk of diarrhea. Further investigation of the association between PCV, TP, IgG, birthweight and neonatal diarrhea on different dairies with different environments seems warranted.

ACKNOWLEDGMENTS

The authors would like to thank the technicians for their work and the owners of the dairies for their cooperation.

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