PHYSIOLOGY AND MANAGEMENT

Effects of Dystocia, Retained Placenta, and Metritis on Milk Yield in Dairy Cows

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ABSTRACT

The effects of dystocia, retained placenta, and metritis on milk yield were studied in 37,776 Finnish Ayrshire cows that calved during 1993; cows were studied for one lactation. Monthly test day milk yields were treated as repeated measurements within a cow in a mixed models analysis. Index categories were created to relate the time of disease occurrence to the test dates and to capture the short-term effects of diseases on milk yield. Diseases other than dystocia, retained placenta, or metritis were categorized into two groups: diseases occurring within 42 d after calving or diseases occurring later than that.

The statistical models for each parity included calving season, stage of lactation, and disease variables as fixed effects. For parities 2, 3, and 4 or higher, the cows were grouped into four categories based on previous lactation milk yield, and the disease effect was studied separately for each yield level. An autoregressive covariance structure was used to model the association among the repeated measurements. Models with a 305-d yield as the outcome were also run; the diseases were treated as binary covariates in these models.

Dystocia, retained placenta, and early metritis significantly affected milk yield, as indicated by monthly test day milk yields. Late metritis was not associated with milk loss. The impact of the diseases differed across parities and also across different levels of milk yield. Using 305-d milk yield as the milk measure, no diseases were associated with reduced milk yield.
(**Key words**: reproductive diseases, milk yield, repeated measures, mixed model analysis)

INTRODUCTION

Diseases mainly affect dairy cow productivity in three ways: 1) by reducing reproductive efficiency, 2) by shortening the expected length of productive life (i.e., by increasing culling risk), and 3) by lowering milk yield. Numerous studies (1, 2, 9, 10, 13) have shown that diseases related to the reproductive tract (dystocia, retained placenta, and metritis) are interrelated and can affect the length of calving interval, the number of days open, and the reproductive efficiency in general. These diseases can also affect the overall productivity of dairy cows by reducing milk yield.

Several statistical approaches have been used to evaluate milk losses from diseases. A basic idea is to compare milk yield from cows with a specific disease with cohorts without the disease. Previously, a summary measure, such as 305-d milk yield, was commonly used to estimate the disease effect on milk yield. Some diseases, however, can have a short-term effect on milk yield that might be compensated for by later yield. Furthermore, because high yield is associated with some diseases (9, 11), using a summary measure, such as 305-d milk yield, might even lead to erroneous conclusions. For example, in general, cows with ketosis produce more milk, even after having contracted the disease, than their healthy herdmates of lower yield (6).

The purpose of this study was to evaluate the effects of dystocia, retained placenta, and metritis on milk yield using repeated, monthly test day milk yields. We also modeled the association between 305-d milk yield and diseases and compared the results from these two approaches for modeling the disease effect on milk yield.

MATERIALS AND METHODS

Data

The data for this study are from 37,776 Finnish Ayrshire dairy cows that calved during 1993 and were followed until the next calving or culling. The cows were in 2337 herds that belonged to the milk registry

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and the national health recording system. The data have been described in detail previously (18).

For this study, three different veterinary diagnoses (dystocia, retained placenta, and metritis) made during the study lactation were considered. All dystocia cases in these data required veterinary assistance, but the nature of the assistance was unknown (e.g., whether a caesarean section was necessary). Furthermore, metritis was divided into two categories based on the time of occurrence: early metritis if the disease was diagnosed within 28 d after calving and late metritis if diagnosed later. The other diagnosed diseases of cows during the study lactation were treated as one of two entities, diseases occurring within 42 d after calving or diseases occurring later than that. Finnish farmers do not have access to veterinary drugs without supervision of a veterinarian, so virtually all diseases were diagnosed and treated by a veterinarian during farm visits. The diagnoses were made by a veterinarian according to ordinary clinical methods under normal field conditions. Only the first occurrence of diseases was considered in this study. The calving dates, disease dates, and dates for sampling monthly test day milk yield were available. Disease occurrences were expressed as lactational incidence risks (12) and were calculated by dividing the number of cows with a particular disease by the total number of cows at risk and then multiplying by 100 (i.e., expressed as percentages).

Monthly test day milk yields, taken at approximately 30-d intervals, were used to study the effect of diseases on milk yield. The lactation was divided into 17 stages: the milk records taken within 60 d after calving were grouped by 10-d intervals, the records from 61 to 180 d were grouped into 20-d intervals, and the records from greater than 181 d formed 30-d intervals. Only test day milk yields until 330 d after calving were considered. Lactation curves for each parity (parities 1, 2, 3, and 4 or higher) were constructed using the monthly test day yields collected during these different lactation stages.

To differentiate between cows with and without a disease, a disease index variable was created for each test day milk yield in order to study the short-term effects of the diseases on milk yield.

The disease index variable for dystocia and retained placenta was defined as follows: 1 for each test day yield collected within 14 d after the diagnosis, 2 for test day yields collected between 15 and 28 d after the diagnosis, 3 for test day yields collected between 29 and 42 d after the diagnosis, 4 for test day yields collected later than 42 d after the diagnosis, and 5 if no dystocia or retained placenta was evident.

The disease index variable for metritis (both early and late metritis) was defined as follows: 1 for test day milk yields collected more than 14 d before the diagnosis, 2 for test day milk yields collected within 14 d before the diagnosis, 3 for each test day yield collected within 14 d after the diagnosis, 4 for test day yields collected between 15 and 28 d after the diagnosis, 5 for test day yields collected later than 28 d after the diagnosis, and 6 if the cow had not been diagnosed with metritis.

Two separate binary variables for disease were also created to account for whether a cow had had diseases other than the three diseases of interest during the lactation: one variable contained any other diseases occurring within the first 42 d after calving, and the second variable included diseases diagnosed later than 42 d after calving.

Four calving seasons were defined by 3-mo intervals; winter, December to February; spring, March to May; summer, June to August; and fall, September to November.

Statistical Analyses

Repeated measurements were present in both space and time. Cows within the same herd were clustered in space, and repeated measurements of monthly milk yields of the same cow were correlated in time. The analysis of the repeated measures data is distinct from simple linear models in the covariance structure of the observed data. In a typical experiment utilizing repeated measures, two measurements taken at adjacent times are typically more highly correlated than two measurements taken several time points apart (14).

One type of statistical analysis that can be used for repeated measures is based on the mixed model with a special parametric structure for the covariance matrices. This type of methodology has been computationally feasible only in recent years and is available in PROC MIXED of SAS (14), typically using the REPEATED statement. This procedure was used for these data with the monthly test day milk yields as the outcome variable. A cow usually has approximately 10 monthly test day milk yields recorded during a lactation. Because milk yield measurements from the same lactation for a cow are correlated, it is important to account for this correlation in estimating the effects of disease on milk yield. Three commonly used correlation patterns (simple, compound symmetry, and first-order autoregressive) were compared to model the shape of the lactation curve for each parity.

In the simple correlation pattern, responses are considered to be uncorrelated, and, in the compound symmetry structure, all correlations between any repeated measurements are equal. For the general autoregressive model, the correlations depend on the time between the repeated observations. In the first-order autoregressive model, the correlations decrease exponentially with the distance, and a measurement is correlated with the previous one. The most suitable correlation pattern for these data was chosen based on Akaike's information criterion and Schwartz's Bayesian criterion and was used when modeling the disease effect on milk yield.

In PROC MIXED, the standard linear model is generalized to form a mixed model: $\mathbf{y} = \mathbf{X}\beta + \mathbf{Z}\gamma + \epsilon$ with $\mathrm{Var}(\gamma) = \mathbf{G}$ and $\mathrm{Var}(\epsilon) = \mathbf{R}$, so that $\mathrm{Var}(\mathbf{y}) = ZGZ' + R$, where $\mathbf{y}$ = vector of test day milk yields, β = vector of fixed effects with a known index matrix $\mathbf{X}$, γ = vector of random herd effects with a design matrix $\mathbf{Z}$, and ϵ = vector of random errors.

A correlation pattern can be modeled in PROC MIXED in two ways, either by introducing the correlation pattern in the random effects, γ, through a nonidentity matrix $\mathbf{G}$ or by an $\mathbf{R}$ matrix so that it equals σ^2 multiplied by some nonidentity matrix.

The effects of diseases on test day milk yields were studied separately for each parity (i.e., parities 1, 2, 3, and 4 or higher). For parities 2, 3, and 4 or higher, the cows were also grouped into four categories based on the previous lactation milk yield, and the disease effect was studied separately for each yield level. First, the effects of the four diseases were modeled separately. Then, the diseases were included in the model simultaneously in addition to the other two disease variables that accounted for whether a cow had been diagnosed with any other diseases at the beginning of lactation or later. Calving season, stage of lactation, and the disease variables were fixed effects in each model. The clustering of cows within herds was accounted for by indicating in the REPEATED statement of the model that cows were nested within herds.

All of these analyses used the milk yield of healthy cows (i.e., cows without the particular disease in question) as a reference level. For late metritis, an extra analysis was run using the milk yield prior to disease onset (more than 4 wk before the diagnosis) of cows with late metritis as the comparison level.

The disease effect on 305-d milk yield was modeled using PROC GLM of SAS. The fixed effects in the model included calving season, stage of lactation, and binary disease variables, indicating whether a cow had had dystocia, retained placenta, early or late metritis, or any other diseases within 42 d after calving or later than that. A separate model was run for each parity. In these models, the herd effect was accounted for with the ABSORB statement.

RESULTS

Table 1 presents basic descriptive statistics for these data, such as number of cows per parity, lactational incidence risks by parity, and the 305-d milk

TABLE 1. Descriptive statistics by parity for 37,776 Finnish Ayrshire cows that calved during 1993.

	Parity			
	1	2	3	4+
Cows, no	11,796	9387	6671	9922
Test day milk samples, no.	115,189	90,566	61,813	85,599
Dystocia, LIR[1]	2.2	1.2	1.8	2.3
Retained placenta, LIR	2.0	2.2	3.3	3.7
Early[2] metritis, LIR	2.7	1.6	2.1	2.3
Late[3] metritis, LIR	1.4	1.2	1.0	1.5
Milk yield[4], kg				
Dystocia	6213	6819	7454	7651
No dystocia	6090	6829	7219	7332
Retained placenta	5950	6799	7357	7601
No retained placenta	6095	6829	7218	7328
Early metritis	6185	6852	7347	7555
No early metritis	6090	6829	7220	7334
Late metritis	6404	7250	7718	7982
No late metritis	6088	6824	7217	7326

[1]Lactational incidence risk (LIR: percentage) = (number of cows with the disease/number of cows at risk at the beginning of lactation) × 100.

[2]Occurred within 28 d after calving.

[3]Occurred later than d 28 after calving.

[4]Milk yield for the current 305-d lactation.

yields from the study lactation (i.e., lactation when the diseases occurred) for cows with and without the diseases across parities.

Table 2 shows the disease frequencies in different milk categories (based on previous lactation 305-d milk yield) for each parity group. The incidences differed significantly ($P = 0.001$) only in parity 4; the highest yielding cows seemed to have the highest frequency for each of the four diseases.

Different correlation structures were used to model the association among the repeated measurements. Each parity was modeled separately; calving season and stage of lactation were fixed effects in the models. The autoregressive correlation pattern resulted in the best fit of the model (Akaike's information criterion and Schwarz's Bayesian criterion were closer to zero than with the two other correlation structures) among all parities. Thus, this correlation structure was used in all the models that contained the disease variables.

Lactation curves for cows in parities 1, 2, 3, and 4 or higher were constructed based on the estimates for the 17 lactation stages obtained from models using the first-order autoregressive correlation structure. The model also included calving season as a covariate. The lactation curves are presented in Figure 1. The lactation curve of parity 1 cows is lower and flatter than those curves for older cows, which rise more sharply and start to decline more rapidly. The peak yield in these data for the cows in parity 1 occurred approximately on d 58 and for older cows was on d 40. The curves are for cows calving in fall.

TABLE 2. Lactational incidence risks[1] of dystocia, retained placenta, and early and late metritis by parity and levels of milk yield.[2]

Parity	Disease	Milk yield quartile 1	2	3	4
2	Dystocia	1.0	1.0	1.3	1.4
	Retained placenta	1.9	2.0	1.9	2.9
	Early metritis[3]	1.1	1.4	1.6	2.0
	Late metritis[4]	1.2	0.8	1.2	1.6
3	Dystocia	1.5	1.8	1.5	2.5
	Retained placenta	2.4	3.6	3.6	3.7
	Early metritis	1.5	2.6	2.0	2.2
	Late metritis	0.7	0.7	1.1	1.4
4+	Dystocia***	1.8	1.9	2.1	3.3
	Retained placenta***	3.1	2.7	4.0	5.2
	Early metritis***	1.8	1.4	2.3	3.5
	Late metritis***	1.0	1.0	1.7	2.3

[1]Lactational incidence risk (percentage) = (number of cows with the disease/number of cows at risk at the beginning of lactation) × 100.

[2]Yield is based on quartiles of the milk yield of the previous 305-d lactation.

[3]Occurred within 28 d after calving.

[4]Occurred later than 28 d after calving.

***The incidences differed in an overall chi-square test (α = 0.001).

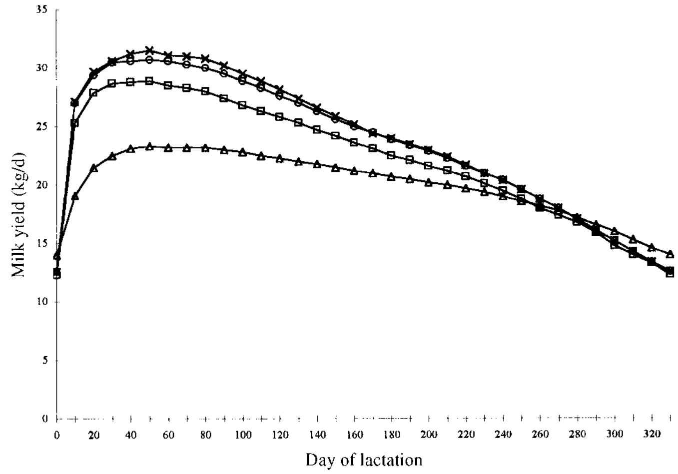

Figure 1. Lactation curves by parity 1 (△), 2 (□), 3 (○), and 4 or higher (x) for one lactation from 39,727 Finnish Ayrshire cows that calved in fall 1993.

When metritis was treated as one disease complex, regardless of the time of its occurrence, metritis had no significant effect ($P > 0.05$) on milk yield (results not shown). However, when early and late metritis were analyzed separately, the time of disease occurrence had an effect on milk yield. Late metritis was not associated with milk loss; on the contrary, cows with late metritis appeared to produce more than cows without it. However, the differences were not statistically significant ($P > 0.05$). Early metritis, however, was associated with reduced milk yield.

The analysis of late metritis using the milk yield level prior to disease as the reference point showed that late metritis did not reduce milk yield (results not shown). This analysis, however, also showed that cows with late metritis were higher yielding, both before and after the disease diagnosis, than were cows without the disease. Cows without late metritis yielded, on average during the lactation, between 0.8 and 1.7 kg/d less milk than did cows diagnosed with the disorder, depending on parity.

The results from the test day models containing all diseases simultaneously are presented in Tables 3, 4, 5, and 6 for parities 1, 2, 3, and 4 or higher, respectively. Calving season and the two binary variables for any other disease were included in the model (estimates for these effects are not shown). The results suggested that cows with any other diseases that occurred later in lactation yielded significantly more milk than did cows without the diseases. Calving season was a significant factor in each model; cows calving during fall had the highest test day milk yield, and cows calving during summer had the lowest test day milk yields.

Parity 1

Dystocia had no effect on milk yield among cows in parity 1 (Table 3). Retained placenta was significantly associated with decreased milk yield among cows in parity 1. Milk loss was 1.4 kg/d during the first 2 wk, 1.1 kg/d during the following 2 wk, 0.7 kg/d for the next 2 wk, and 0.5 kg/d thereafter. Early metritis was associated with significant milk loss before the diagnosis that continued after the diagnosis, even though the effect was not statistically significant. Cows in parity 1 that had early metritis lost 1.4 kg/d during the 2 wk just before the diagnosis. When early metritis was modeled alone (i.e., without adjustment for dystocia and retained placenta), the effect was significant earlier (a loss of 2.3 kg/d more than 2 wk before the diagnosis).

Parity 2

Dystocia significantly decreased milk yield (ca. 2.2 kg/d during the first 2 wk) among cows in parity 2. However, among the lowest yielding cows, dystocia did not have a significant effect, and cows yielding the most lost on average 4.9 kg of milk/d during the first 2 wk after calving (Table 4). Among cows in parity 2, the milk loss caused by retained placenta was greatest among the highest yielding cows: 3.4 kg/d, 3.5 kg/d, and 1.9 kg/d during the first 2 wk after the diagnosis, between wk 2 and 4, and between wk 4 and 6 after the diagnosis, respectively. The percentage loss of average yield for cows in the lowest quartile was 0.6%, and, in the highest quartile, the percentage loss was 1.6%. Cows in parity 2 with early metritis lost 1.3 kg/d within 2 wk after the diagnosis. The lowest yielding cows lost 2.8 and 3.6 kg/d during the 2 wk before and after diagnosis, respectively. Among the highest yielding cows, the effect of early metritis was a loss of 3.5 kg/d more than 2 wk before the diagnosis; however, this loss was not statistically significant (Table 4).

Parity 3

Dystocia did not have a significant effect on milk yield among cows in parity 3 if the presence of retained placenta and metritis and the other diseases was accounted for (Table 5). However, the highest yielding cows were affected by dystocia, losing 2.6 kg/d during the first 2 wk after diagnosis (borderline significance, $P < 0.1$) and 1.7 kg/d later in the lactation. When modeled alone, the mean milk loss from dystocia among cows in parity 3 was 2.2 kg/d during the first 2 wk after calving. The milk yield of cows in parity 3 was not affected by retained placenta when the presence of any other diseases was accounted for, but, when the effect of retained placenta was modeled alone, the cows lost 1.7 kg/d during the first 2 wk after diagnosis. For the highest yielding cows in parity 3, the loss was 2.7 kg/d for the first 2 wk after diagnosis. The loss from early metritis was 4.2 kg/d before diagnosis; the total loss was remarkably higher when the effects of retained placenta and dystocia were not accounted for (5.7 kg/d during the first 2 wk and 2.0 kg/d and 2.1 kg/d during the following two 2-wk periods) (Table 5).

TABLE 3. Effects of dystocia, retained placenta, and early metritis (within 28 d after calving) on test day milk yields (kilograms) of Finnish Ayrshire cows in parity 1 that calved during 1993.[1]

Disease[2] occurrence	Estimate	SE
Dystocia		
0–14 d PP	–0.7 (–0.8)[4]	0.4 (0.5)
15–28 d PP	–0.1 (0.1)	0.4 (0.4)
29–42 d PP	–0.2 (0.2)	0.4 (0.4)
>42 d PP	0.1 (0.4)	0.2 (0.2)
Total loss[3]		
Retained placenta		
0–14 d AD	–1.4*** (–1.5***)	0.4 (0.4)
15–28 d AD	–1.1** (–1.2**)	0.4 (0.4)
29–42 d AD	–0.7* (–0.7)	0.4 (0.4)
>42 d AD	–0.5* (–0.5)	0.2 (0.2)
Total loss	–175.3 (–37.6)	
Early metritis		
>14 d BD	–1.7 (–2.3*)	1.5 (1.2)
1–14 d BD	–1.4** (1.0**)	0.4 (0.4)
0–14 d AD	–0.4 (–0.5)	0.4 (0.3)
15–28 d AD	–0.4 (–0.3)	0.3 (0.3)
>28 d AD	–0.1 (0.2)	0.2 (0.3)
Total loss	–19.6 (–46.2)	

[1]The model included also, as fixed effects, calving season and the two other binary disease variables indicating whether a cow had had any other diseases within 42 d after calving or later than that, but the results are not shown.

[2]Period when the test day milk sample was collected with respect to the diagnosis of the disease (PP = postpartum, BD = before diagnosis, and AD = after diagnosis).

[3]Total loss was calculated by summing (14 × a significant daily loss in a defined period) and assuming a 305-d lactation and retained placenta to have been diagnosed on d 2.

[4]Numbers in parentheses are standard errors for the diseases modeled individually.

*$P \le 0.05$.

**$P \le 0.01$

***$P \le 0.001$.

Parity 4 or Higher

Dystocia was not associated with milk loss among the oldest cows (parity 4 or higher). On the contrary, for the period of 2 to 4 wk after calving, cows with dystocia yielded significantly more milk than did cows that calved without veterinary assistance. On average, retained placenta did not have a significant effect on the milk yield of these cows either. However, cows with retained placenta in the highest yield category lost about 2.2 kg/d during the first 2 wk and then 1.7 kg/d for the following 2 wk, and cows in the lowest milk yield category lost 2.1 kg/d for the first 2 wk after diagnosis (Table 6). Early metritis did not have a significant effect on test day milk yields on average; however, the lowest yielding cows lost 2.8 kg/d, and the highest yielding cows lost 2.7 kg/d during the 2 wk after diagnosis.

None of the diseases was associated with milk loss when 305-d milk yield was the outcome (results not shown). Only late metritis and diseases occurring later than 42 d after calving were significantly associated with 305-d yield; these diseases were associated with higher lactational milk yield.

DISCUSSION

Several statistical approaches (3, 5, 8, 15, 17) have been used to evaluate the milk loss from diseases. When estimating milk yield, earlier researchers focused on the entire 305-d lactation curve. However, when estimating the amount of milk lost as a consequence of a disease, a summary measure such as 305-d milk yield cannot capture short-term fluctuations or decreases in milk yield (6). The use of repeated measurements of milk yield, collected by certain intervals during a lactation, will enable researchers to reveal the patterns of milk loss caused by certain diseases more accurately and in much more detail (5, 6). This pattern is also evident in our results.

When using, for example, monthly recorded milk measurements, however, one should consider that

TABLE 4. Effects of dystocia, retained placenta, and early metritis (within 28 d after calving) on test day milk yields (kilograms) in Finnish Ayrshire cows of parity 2 that calved in 1993.[1]

Disease[2] occurrence	All milk yield categories		Lowest quartile		Highest quartile	
	Estimate	SE	Estimate	SE	Estimate	SE
Dystocia						
0–14 d PP	–2.2*** (–2.3***)[3]	0.7 (0.7)	–1.5 (–1.9)	1.4 (1.4)	–4.9*** (–4.8***)	1.4 (1.4)
15–28 d PP	–1.0 (–1.1)	0.6 (0.6)	–0.2 (–0.4)	1.1 (1.1)	–1.0 (–1.1)	1.2 (1.2)
29–42 d PP	0.3 (0.3)	0.6 (0.6)	1.4 (1.2)	1.2 (1.2)	0.5 (0.6)	1.2 (1.2)
>42 d PP	0.0 (0.1)	0.3 (0.4)	–0.9 (–1.0)	0.7 (0.7)	0.5 (0.6)	0.8 (0.8)
Total loss[4]	–30.8 (–32.2)				–68.6 (–67.2)	
Retained placenta						
0–14 d AD	–1.4** (–1.3*)	0.5 (0.7)	–1.0 (–1.9*)	0.9 (0.9)	–3.4** (–3.6***)	1.1 (1.0)
15–28 d AD	–1.5*** (–1.2*)	0.5 (0.6)	–1.8* (–2.0*)	0.9 (0.8)	–3.5*** (–3.5***)	0.8 (0.8)
29–42 d AD	–0.5 (–0.2)	0.4 (0.6)	–1.2 (–1.2)	0.9 (0.9)	–1.9* (–1.8*)	0.9 (0.9)
>42 d AD	–0.4 (–0.1)	0.3 (0.4)	–0.5 (–0.7)	0.5 (0.5)	–1.1 (–0.9)	0.6 (0.6)
Total loss	–40.6 (–35.0)		–25.2 (–54.6)		–123.2 (–124.6)	
Early metritis						
>14 d BD	–3.2 (2.0)	1.7 (1.3)	1.5 (1.3)	3.5 (3.5)	–3.5 (–4.5)	2.5 (2.5)
1–14 d BD	–0.7 (–0.1)	0.7 (0.6)	–2.8* (–3.3*)	1.4 (1.4)	1.4 (–0.1)	1.6 (1.6)
0–14 d AD	–1.3* (–1.2*)	0.6 (0.6)	–3.6** (–3.9***)	1.2 (1.2)	–0.4 (–0.5)	1.2 (1.2)
15–28 d AD	–0.1 (–1.0)	0.5 (1.0)	–1.9 (–1.9)	1.1 (1.1)	0.9 (0.6)	1.0 (1.0)
>28 d AD	–0.2 (0.1)	0.4 (4.6)	–0.7 (–0.9)	0.7 (0.8)	0.6 (0.5)	0.7 (0.7)
Total loss	–18.2 (–16.8)		–89.6 (–100.8)			

[1]Milk yield is previous lactation 305-d yield. The model included calving season as a fixed effect and also two other binary disease variables indicating whether the cow had had any other disease within 42 d after calving or later (estimates not shown).

[2]Period when the test day milk sample was collected with respect to the diagnosis of the disease (PP = postpartum, BD = before diagnosis, and AD = after diagnosis).

[3]Numbers in parentheses are standard errors for diseases modeled individually.

[4]Total loss was calculated assuming 305-d lactation and retained placenta were diagnosed and treated on d 2.

*$P \le 0.05$.

**$P \le 0.01$.

***$P \le 0.001$.

repeated measurements from the same cow during one lactation are correlated to obtain valid results. A mixed model analysis technique, PROC MIXED of SAS (15), was used in this study; this technique allowed the use of different correlation structures to be applied to the repeated measurements. We tested the suitability of three of the commonly used correlation patterns for our data. The first-order autoregressive correlation structure provided the best fit of the model with monthly test day milk yields as the outcome. The results also make sense biologically; the value for a given test day milk yield is correlated with the measurement taken just before it, and the correlation between two measures becomes smaller as the distance between the measures increases.

Several studies (2, 8, 10, 11) have shown that diseases involving the reproductive tract are interrelated. Our results suggest that they are also interrelated in their effects on milk yield. For example, the effects of retained placenta could be confounded by dystocia and also by any other disease occurring at the beginning of lactation. Therefore, we modeled all of these diseases together to obtain the actual effect of each disease. In general, the disease effects on milk yield from the models that contained all of the diseases simultaneously were smaller than when the diseases were modeled individually. Thus, if the presence of diseases other than the disease of interest is not accounted for, the estimates obtained will likely overestimate the effect that could truly be attributed to that one disease.

We found that the effect of dystocia on milk yield varied among cows in different parities. The milk production of parity 1 cows was not affected at all by dystocia, but dystocia had an impact on the yield of older cows (parities 2 and 3). The effect also varied according to the yield of the cow (based on the previous lactation 305-d yield). Lucey et al. (16) and Rowlands and Lucey (19) found that dystocia had no effect on yield. Dematawewa and Berger (4), however, reported considerable milk loss as a result of difficult calvings. Also, Djemali et al. (7) reported that cows produced more in lactations following an easy birth. Simerl et al. (20) found that stillbirth and dystocia had a statistically significant detrimental effect on milk yield among first lactation cows.

TABLE 5. Effects of dystocia, retained placenta, and early metritis (within 28 d after calving) on test day milk yields (kilograms) in Finnish Ayrshire cows of parity 3 that calved in 1993.

Disease occurrence	All milk yield categories		Lowest quartile		Highest quartile	
	Estimate	SE	Estimate	SE	Estimate	SE
Dystocia						
≤14 d PP[1]	–0.7 (–2.2**)[2]	0.7 (0.8)	–1.2 (–1.6)	1.1 (1.1)	–2.6 (–2.8)	1.6 (1.5)
15–28 d PP	–0.5 (–1.0)	0.6 (0.6)	–1.0 (–1.3)	1.7 (1.7)	–1.4 (–1.2)	1.2 (1.2)
29–42 d PP	–0.9 (–0.7)	3.1 (0.7)	1.2 (0.0)	1.2 (1.0)	–1.6 (–1.6)	1.2 (1.2)
>42 d PP	. . .	. . .	0.4 (0.1)	0.8 (0.8)	–1.7* (–1.6*)	0.8 (0.8)
Total loss[3]	(–30.8)				–447.1 (–420.8)	
Retained placenta						
≤14 d AD[4]	0.3 (–1.7**)	0.5 (0.6)	–2.2 (–2.1)	1.2 (1.2)	–2.7* (–2.9**)	1.2 (1.2)
15–28 d AD	–0.4 (–0.3)	0.4 (0.4)	–0.5 (–0.6)	0.9 (0.9)	0.3 (0.2)	0.9 (0.9)
29–42 d AD	0.1 (0.3)	2.3 (0.5)	1.2 (1.2)	1.2 (1.2)	–0.8 (–0.9)	1.0 (0.9)
>42 d AD	–2.4 (0.2)	4.4 (0.3)	0.3 (0.2)	0.6 (0.6)	0.1 (–0.0)	0.6 (0.6)
Total loss	(–23.8)				–37.8 (–40.6)	
Early metritis						
>14 d BD	–4.2** (–5.7***)	1.7 (1.8)	–5.2 (–5.2)	2.7 (2.7)	–4.6 (–5.1)	4.5 (4.6)
1–14 d BD	–0.1 (–2.0**)	0.6 (0.7)	–3.3** (–3.6**)	1.3 (1.3)	–0.3 (–0.5)	1.5 (1.5)
0–14 d AD	–0.5 (–2.1***)	0.6 (0.6)	–1.9 (–1.8)	1.3 (1.3)	–1.4 (–1.9)	1.3 (1.3)
15–28 d AD	0.0 (–0.6)	0.9 (0.5)	–2.0 (–2.0)	1.2 (1.2)	0.1 (0.0)	1.1 (1.1)
>28 d AD	. . . (–0.1)	. . . (0.4)	–1.2 (–1.3)	0.8 (0.8)	0.7 (0.6)	0.7 (0.7)
Total loss	–58.8 (–137.2)		–46.2 (–50.4)			

[1]Milk yield is previous lactation 305-d yield. The model included calving season as a fixed effect and also two other binary disease variables indicating whether the cow had had any other disease within 42 d after calving or later (estimates not shown).

[2]Numbers in parentheses are standard errors for the diseases modeled individually.

[3]Period when the test day milk sample was collected with respect to the diagnosis of the disease (PP = postpartum, BD = before diagnosis, and AD = after diagnosis).

[4]Total loss was calculated assuming 305-d lactation and retained placenta diagnosed and treated on d 2.

*$P \leq 0.05$.

**$P \leq 0.01$.

***$P \leq 0.001$.

The discrepancies between studies might result from the different statistical methods and milk measures used to estimate the milk loss and also from differences in whether the effects of other diseases were accounted for in the analysis. Also, different definitions of dystocia could be a source of the discrepancies. Some reports use dystocia scores, usually from 1 to 5, to indicate the level of difficulty of the calving; others report only assisted calving. In these data, all diseases were recorded by a veterinarian, and the dystocia cases in our data required veterinary assistance. However, the nature of the assistance remains unknown (i.e., whether caesarean section or pulling of a large calf).

If we were to make our conclusions based only on the summary measure of 305-d yield, we could conclude that dystocia had no effect on milk yield of older cows (parity 2 and 3). It could also be concluded, falsely, that dystocia actually had a beneficial effect on milk yield of cows in parity 1 and in parity 4 or higher because the 305-d milk yield of cows with dystocia in these parities was significantly higher than that of cows without, which could be a reason why we were not able to show a significant reduction in daily yields. Our comparison level was the milk yield level of the healthy cows. Use of late lactation milk yield level of cows with dystocia as the baseline might have been a better way to reveal the detrimental, short-term effects of difficult calvings.

In our data, retained placenta had a significant negative effect on milk yield for several weeks after calving, which is in agreement with results of several other studies. Lucey et al. (16) found that retained placenta suppressed milk yield for about 4 wk after calving, and Rowlands and Lucey (19) reported that retained placenta reduced peak yield, but also had a more lasting negative effect. They estimated a 7% reduction in 305-d yield for cows with retained placenta. In the study of van Werven et al. (21), older cows showed decreased milk yield with an increase in the duration of retention of the placenta. Simerl et al. (20) found milk yield in first lactation to be depressed by retained placenta. Deluyker et al. (3) reported that retained placenta was followed by lo-

TABLE 6. Effects of dystocia, retained placenta, and early metritis (occurred within 28 d after calving) on test day milk yields (kilograms) in Finnish Ayrshire cows of fourth or higher parity that calved in 1993.[1]

Disease[2] occurrence	All milk yield categories		Lowest quartile		Highest quartile	
	Estimate	SE	Estimate	SE	Estimate	SE
Dystocia						
≤14 d PP	0.1 (–1.1)[3]	0.6 (0.7)	0.1 (–0.9)	1.1 (1.1)	–1.3 (–2.4*)	1.0 (1.0)
15–28 d PP	1.7** (1.3*)	0.6 (0.6)	–0.3 (–0.3)	1.0 (1.0)	0.4 (–0.2)	0.9 (0.9)
29–42 d PP	–0.7 (–0.2)	1.5 (0.6)	–0.6 (–0.6)	1.0 (1.0)	–1.6 (–2.2*)	0.9 (0.9)
>42 d PP	. . . (1.2**)	. . . (0.4)	0.3 (0.3)	0.6 (0.6)	–0.1 (–0.5)	0.6 (0.6)
Total loss[4]					(–64.4)	
Retained placenta						
≤14 d AD	–0.0 (0.5)	0.4 (0.4)	–2.1* (–1.8*)	0.9 (0.9)	–2.2** (–2.5***)	0.7 (0.7)
15–28 d AD	0.0 (–0.0)	0.4 (0.4)	–0.6 (–0.6)	0.7 (0.7)	–1.7* (–2.0**)	0.7 (0.7)
29–42 d AD	1.0 (0.8)	1.9 (1.7)	–0.5 (–0.3)	0.8 (0.8)	0.1 (–0.1)	0.7 (0.7)
>42 d AD	. . . (0.6)	. . . (0.3)	–0.7 (–0.5)	0.4 (0.4)	–0.3 (–0.5)	0.4 (0.4)
Total loss			–29.4 (–25.5)		–54.6 (–63.0)	
Early metritis						
>14 d BD	–1.1 (–1.4)	1.7 (1.7)			–3.4 (–4.4)	2.4 (2.4)
1–14 d BD	–0.0 (–0.8)	0.6 (0.6)	–1.9 (–2.3)	1.5 (1.4)	–0.7 (–1.1)	1.0 (1.0)
0–14 d AD	–1.0 (–1.5**)	0.6 (0.5)	–2.8** (–2.5**)	1.0 (1.0)	–2.7** (–2.9**)	0.9 (0.9)
15–28 d AD	–0.5 (0.2)	0.9 (0.5)	0.2 (0.4)	0.9 (0.9)	–0.5 (–0.5)	0.8 (0.8)
>28 d AD	5.6 (0.5)	4.5 (0.3)	–0.0 (0.2)	0.6 (0.6)	–0.6 (–0.6)	0.5 (0.5)
Total loss	. . . (–21.0)		–39.2 (–35.0)		–37.8 (–40.6)	

[1]Milk yield is previous lactation 305-d yield. The model included calving season as a fixed effect and also two other binary disease variables indicating whether the cow had had any other disease within 42 d after calving or later than that (estimates are not shown).

[2]Period when the test day milk sample was collected with respect to the diagnosis of the disease (PP = postpartum, BD = before diagnosis, and AD = after diagnosis).

[3]Numbers in parentheses are standard errors for the diseases modeled individually.

[4]Total loss = $\Sigma(14 \times$ a significant daily loss in each period).

*$P \le 0.05$.

**$P \le 0.01$.

***$P \le 0.001$.

wered mean values for yield during the first 5 d after calving. Martin et al. (17), however, found no yield effect from retained fetal membranes. They used 305-d milk yield as their milk measure.

Our data might overestimate the overall effect of retained placenta, because disease occurrences are based on veterinary diagnosis, followed by treatments administered by veterinarians. In Finland, retained placenta is often left untreated unless the cow shows systematic symptoms (e.g., fever or inappetence). Therefore, the cases that are recorded into the Finnish database are most likely the most severe cases, and, therefore, we might have overestimated the overall effect of retained placenta. It is possible that, if a cow is sick or on antibiotic treatment on a test day, the milk yield of that cow would not be measured at all, and an underestimation of the real milk loss would occur. Also, if a cow died or was culled early in the lactation before test day data were recorded, an underestimation of the milk loss could result.

The milk yield of cows with these diseases was compared with that of healthy cows. If cows with these diseases had a higher yield than did healthy cows, our method probably underestimated the true effect of the disease on milk yield; contracting the disease in such a case would only have brought the yield to the same level as that of the healthy cows. Late metritis was the only disease in this study that occurred later in lactation so that the milk yield of each cow prior to disease could be used for comparison. Results using this method, however, ensured that late metritis truly did not have a negative effect on milk yield. For those diseases that occurred so early in lactation that no milk measures could be taken before the disease, the yield of the cow in late lactation could have been used. Loss of milk yield from those diseases would probably have been shown to be greater using that baseline and within-cow comparisons.

Metritis, as one diagnosis, did not have any effect on milk yield in these data, which agreed with the results of Lucey et al. (16) and Rowlands and Lucey (19). Deluyker et al. (3), however, reported milk loss from metritis. When early and late metritis were analyzed separately, the importance of the timing of the disease on milk loss became apparent. Late metritis did not have a significant effect on milk yield, but early metritis significantly reduced milk yield. This result could be explained by the possibility that the cases of early metritis might have been more severe and might have included such systematic symptoms as high temperature and inappetence, possibly resulting from difficult calving or retained placenta. Dohoo and Martin (8), however, reported that the infection of the reproductive tract diagnosed within 21 d postpartum did not have a detrimental effect on milk yield per day of life. Part of the effect of early metritis in our study, which was evident even before the diagnosis, can be attributed to dystocia and retained placenta; the effect of metritis was slightly reduced when dystocia and retained placenta were added to the model.

Using 305-d milk yield as the outcome measure, we could not find an effect of the diseases on milk yield. In our data, if a cow died or was culled during the lactation, there were no records on her 305-d milk yield from that lactation. Thus, if the low yielding cows that were severely affected by a disease were culled and the higher yielding cows were left in the herd, estimates of the effects of the diseases would be biased.

Among cows with dystocia and retained placenta, there was a tendency within each parity for the highest yielding cows to lose more milk than average or lower yielding cows. This result suggests that higher yielding cows also have a potential to lose more. Older cows in general yield more than do younger cows, but no clear trend of greater milk loss could be found in these data as parity increased.

CONCLUSIONS

This study showed that using repeated measurements for monthly test day milk samples to estimate the milk loss from diseases gives more detailed results than using a summary measure, such as 305-d milk yield. Repeated measures analysis can capture more accurately short-term changes, which remain unnoticed in a summary measure. The first-order autoregressive correlation structure gave the best fit when modeling the correlation among monthly test day milk yields.

Dystocia, retained placenta, and early metritis had a significant effect on milk yield, mostly in early lactation. The impact of these diseases varied across parities and also across different milk yield levels. The absolute milk loss seemed to increase as the amount of milk that the cow produced increased, which indicates that higher yielding cows may also have a greater potential for loss.

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