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## Associations between somatic cell count patterns and the incidence of clinical mastitis

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### Abstract

Associations between clinical mastitis (CM) and the proportional distribution of patterns in somatic cell count (SCC) on a herd level were determined in this study. Data on CM and SCC over a 12-month period from 274 Dutch herds were used. The dataset contained parts of 29,719 lactations from 22,955 cows of different parities. In total, 207,079 SCC test-days were recorded with 5719 cases of CM; 1561 cases were associated with environmental pathogens (ENV\_CM), and 2681 with contagious pathogens (CONT\_CM). Definitions of patterns in SCC were based on 3, 4, or 5 consecutive test-day recordings of SCC that differentiated between short or longer periods of increased SCC, and also between lactations with and without recovery. The distribution of those patterns (relative to their maximum) varied among herds. The distribution of SCC patterns was correlated with the incidence rate of CM. Herds with a relatively frequent quick recovery pattern had a 2.5 times more chance of being classified in the upper quartile for CM. These herds also had 2.1 times more chance of being classified in the upper quartile for ENV\_CM but only 0.4 times for CONT\_CM. Herds with a relatively frequent no recovery pattern had less chance (odds ratio = 0.5) of being classified in the lower quartile for CONT\_CM. Since the distributions of SCC patterns were indicative for overall, environmental and contagious CM, the necessity to

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introduce pathogen-specific mastitis control programs in a herd could be determined based on the mean incidences of SCC patterns in that herd.

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## 1. Introduction

Mastitis-causing pathogens can be categorised into environmental and contagious pathogens (Fox and Gay, 1993; Smith and Hogan, 1993). *Escherichia coli* is the most important environmental pathogen (Smith and Hogan, 1993). The primary reservoir of environmental pathogens is the environment of the dairy cow. Exposure of udder quarters to these pathogens may occur at any time, independent of the presence of infections in herd mates (Zadoks et al., 2001). The incidence rate of clinical mastitis (CM) associated with environmental pathogens is mostly related to housing conditions, hygiene and milking machine management (Bartlett et al., 1992; Barkema et al., 1999). *Staphylococcus aureus* is the most important contagious pathogen (Fox and Gay, 1993), and its primary reservoir is the infected animal or udder quarter, and its transmission is largely determined by the milking procedure and the milking machine (Schukken et al., 1991; Barkema et al., 1999). *Streptococcus agalactiae* and *Streptococcus dysgalactiae* are usually referred to as contagious (Hillerton et al., 1995), but most other streptococci are considered to be environmental pathogens (Smith et al., 1985; Pankey et al., 1987). However, cow-to-cow transmission of *Streptococcus uberis* has also been reported (Zadoks et al., 2001), as well as persistent *E. coli* mastitis with recurrent cases (Döpfer et al., 1999; Bradley and Green, 2001). Zadoks (2002) discussed the option of classifying mastitis-causing pathogens on a sliding scale, where the balance of contagious and environmental transmission shifts gradually, rather than using a species-based dichotomy.

A large number of control measures have been developed, and are combined in mastitis control programs (Park and Morgan, 1981; Oliver and Mitchell, 1984). Procedures that may be very successful in control or eradication of contagious mastitis, may not be effective in the control of environmental mastitis, and vice versa (Neave et al., 1969; Fox and Gay, 1993; Smith and Hogan, 1993). Standard mastitis control programs (Neave et al., 1969) can decrease the prevalence of intramammary infections (IMI) with contagious pathogens (Neave et al., 1969; Hillerton et al., 1995), but are less successful in preventing new cases of CM from environmental pathogens (Schukken et al., 1990; Lam et al., 1997; Barkema et al., 1999). Recommendations to control both contagious and environmental pathogens have been combined in a new 10-point mastitis control program, issued by the National Mastitis Council (2001).

Information about the lactation-average somatic cell count (SCC) is used as part of mastitis control programs, but individual test-day SCCs can be used instead. Effective use of SCC test-day records may be achieved by defining patterns in the SCC during the lactation (De Haas et al., 2004). However, it has not been assessed whether these SCC patterns provide more information on the pathogen-distribution on a farm, and the success

of therapy than the lactation-average SCC. If they do, health management advice can then be directed specifically on lowering the incidence rate of pathogen-specific CM, or shortening the duration of infection. Therefore, the aim of this study was to determine associations between incidence rates of pathogen-specific CM and the presence of patterns in the SCC at the herd level.

## 2. Materials and methods

### 2.1. Herds

Records on CM were available from a longitudinal prospective cohort study for the period from December 1992 until June 1994 on 274 Dutch farms (Barkema et al., 1998). Lactating cows were housed in free-stall barns and milking parlours were double herringbone or two-sided open tandem. All herds participated in a milk recording system, and annual milk production quotas were between 300,000 and 900,000 kg. The main breeds were Holstein-Friesian, Dutch-Friesian and Meuse-Rhine-Yssel. The national milk recording system (NRS, Arnhem, The Netherlands) provided information from the three- or four-week milk recordings, including: national cow identification, breed, date of milk recording, date of calving, date of drying off, test-day milk yields and SCC.

### 2.2. Sampling

Herd selection and sampling procedures were described previously (Barkema et al., 1998). During the study period, farmers took milk samples from all quarters that, in their opinion, had clinical signs of mastitis, such as abnormal texture and discoloration of the milk, swelling and discoloration of the udder, increased temperature or pain of the quarter. Quarter samples were stored in a freezer at the farm (at approximately  $-20^{\circ}\text{C}$ ) and were collected for bacteriological examination at intervals of 6–8 weeks. Bacteriological culturing of milk samples was performed according to the standards of the National Mastitis Council (Harmon et al., 1990). Briefly, 0.01 ml was cultured, and for each culture, the number of colony-forming units of each of the bacterial species was counted. The data included national cow identification number, date of mastitis occurrence, quarter infected, and result of bacteriological culturing of milk sample. Two groups of pathogens were defined: (1) contagious pathogens (CONT\_CM) (Fox and Gay, 1993), consisting of *S. aureus*, coagulase negative staphylococci and *S. dysgalactiae*, and (2) environmental pathogens (ENV\_CM) (Smith and Hogan, 1993), consisting of *E. coli* and *S. uberis*. Intervals between cases of CM in the same quarter had to be  $\geq 14$  days for a CM to be included as a new case (Barkema et al., 1998).

### 2.3. Data selection

Initially, valid records on CM and bacteriological characterisation were available on 47,563 lactations (De Haas et al., 2002a). For the present study, only the first 365 days of

the study were selected from the dataset, because the aim of the study was to investigate the possibilities of giving health management advice based on information from the past year in a herd. Therefore, the final dataset consisted of 29,719 (parts of) lactations from 22,955 cows. In total, 207,079 SCC test-days were recorded. All cases of CM in the year of observation were noted ( $n = 5719$ ), of which 1561 were associated with environmental pathogens, and 2681 with contagious pathogens. However, not every case of CM was covered by these two groups, because some bacteriological examinations were culture-negative (14.8% of all bacteriological examinations), or because the case of CM was associated with other pathogens, such as *Corynebacterium bovis* or *Klebsiella* spp., or because the samples were contaminated (11.3% of all collected samples). In total, 15% of all cases of CM were associated with cultures of both environmental and contagious pathogens, and these cases were scored for both pathogens.

## 2.4. Definitions

### 2.4.1. Mastitis

The herd incidence rates for CM, CONT\_CM and ENV\_CM were expressed per cow-day at risk. Cow-days at risk was calculated as the total number of days during the year of observation that each cow was in milk. For each case of CM 14 days was subtracted from the days in milk.

### 2.4.2. Patterns of SCC

Patterns of SCC were used to distinguish lactations with short or longer periods of increased SCC, and also lactations with and without recovery from the increase in SCC. Healthy and recovered cows were assumed to have less than 200,000 somatic cells/ml (Dohoo and Leslie, 1991), and cows with intramammary infections were assumed to have more than 500,000 cells/ml (Lam et al., 1997). Therefore, test-day recordings of SCC were categorised as low when the uncorrected SCC measured was  $< 200,000$  cells/ml, and when the uncorrected SCC was  $> 500,000$  cells/ml, the test-day recording of SCC was categorised as high. An intermediate category was defined for  $SCC \geq 200,000$  and  $\leq 500,000$  cells/ml.

Five patterns of SCC were defined based on these three categories.

- The first SCC pattern (P1) is referred to as a “quick recovery pattern”, and described consecutive test-day recordings of SCC that were low–high–low.
- The second pattern (P2) is referred to as a “slow recovery pattern” and described test-day recordings of SCC that were low–intermediate–high–intermediate–low, respectively.
- The third pattern (P3) is referred to as a “no recovery pattern” and denoted a test-day with a low SCC followed by four test-days with high SCC.
- The fourth pattern (P4) is referred to as a “shorter no recovery pattern” and denoted 4 test-day recordings of SCC that were low, high, high, and high.
- The fifth pattern (P5) is referred to as the “shortest no recovery pattern” and denoted 3 test-day recordings of SCC that were low, high, and high, consecutively.

The above patterns were determined per cow (De Haas et al., 2004). Only fully completed patterns were considered, and more than one pattern could have been present per cow. The numbers of SCC patterns were 2662, 361, 860, 1082 and 2353 for the patterns 1–5, respectively.

The proportional distribution of each SCC pattern refers to the ratio of the number of a SCC pattern observed during the year of observation to the maximum feasible number of occurrences of that SCC pattern in the population at risk. The maximum feasible number of SCC patterns depended on the number of consecutive test-day records of individual cows and on the length of the patterns. For example, if a cow had 15 consecutive test-day records, and P1 required 3 test-day recordings, then for any pattern starting up to the 13th test-day it is possible to assign it as a P1 or not. A pattern starting on the 14th or 15th test-day can not be finished completely: therefore, the maximum feasible number of P1's for this cow would be 13. These maximum feasible number of SCC patterns of the individual cows were summed per herd. For instance, when a herd with 100 cows that participate in the 3-week milk-recording, each cow could have 15 test-day recordings per lactation. Therefore, in theory, 1300 P1's could have been observed, but the proportional distribution describes how many P1's were actually observed, relative to this number.

#### 2.4.3. Current SCC parameters

Current SCC parameters are the number of new infections (INF), and the total number of test-days with SCC recorded above 250,000 cells/ml (H\_SCC). An INF was defined by a low SCC ( $\leq 250,000$  cells/ml) shifting to a high ( $> 250,000$  cells/ml) test-day recording. The proportional distribution of INF was calculated per herd by dividing the total number of INF by the maximum feasible number of INF that could have been determined in that herd. The proportional distribution of H\_SCC was calculated by dividing the number of test-days with  $> 250,000$  somatic cells/ml by the total number of SCC test-day recordings in a herd.

#### 2.5. Statistical analyses

The variation between herds of the proportional distribution of the SCC patterns and of the current SCC parameters was investigated using the 10, 25, 50, 75 and 90% deciles.

To compare herd rankings, spearman rank correlations between mastitis rates and proportional distributions of SCC patterns and current SCC parameters were estimated using PROC CORR in SAS (SAS/STAT<sup>®</sup>, 2001).

The incidence rate of CM was described at different levels of both P1 and P5 distributions. It was decided to analyse the effect of these two SCC patterns because they were equally long and differentiated between a quick and no recovery from the infection. To accomplish this, an interaction between a spline describing the incidence rate of CM as a function of P1 or P5 was modeled. A smoothing spline function was fitted in AS-REML (Gilmour et al., 2002). Usually, a spline function is used for smoothing data points and the function allows maximum flexibility and assumes no prescribed curvature. A spline is constrained so that the function and its first two derivatives are continuous at the breakpoints between one segment and the next. The 'predict' statement in AS-REML was

used to predict the incidence rates of the mastitis outcomes at different values of the ratios of SCC patterns.

To test if there was an association between SCC pattern frequency and the occurrence of CM, statistical analyses were carried out using logistic regression in SAS (PROC LOGISTIC; (SAS/STAT<sup>®</sup>, 2001)). Odds ratios (OR) were calculated between the 25% of herds with the lowest CM and the 25% herds with the lowest or highest ratio of SCC patterns. Similar analyses were performed with the 25% herds with the highest CM. The 25% herds with the lowest CM were compared to the rest (i.e. 75%), and in a separate analysis, the 25% herds with the highest CM were compared to the rest. The predictors indicated whether or not a herd was classified in the best (b) or worst (w) 25% of herds based on the SCC patterns.

### 3. Results

Ratios of SCC patterns varied among herds (Fig. 1). The distribution of the slow recovery and no recovery patterns seemed to be negative binomially distributed, and that of the quick recovery pattern appeared to be almost normally distributed. Also, the proportional distribution of the SCC patterns and the current SCC parameters differed among the 10, 25, 50, 75 and 90% deciles (Table 1).

The estimated Spearman rank-order correlations among SCC patterns indicated that herd rankings differed for the separate SCC patterns (Table 2). Low correlations existed between the quick or slow recovery patterns and the other SCC patterns, and moderate to high correlations existed between all 3 no recovery patterns and the other SCC patterns.

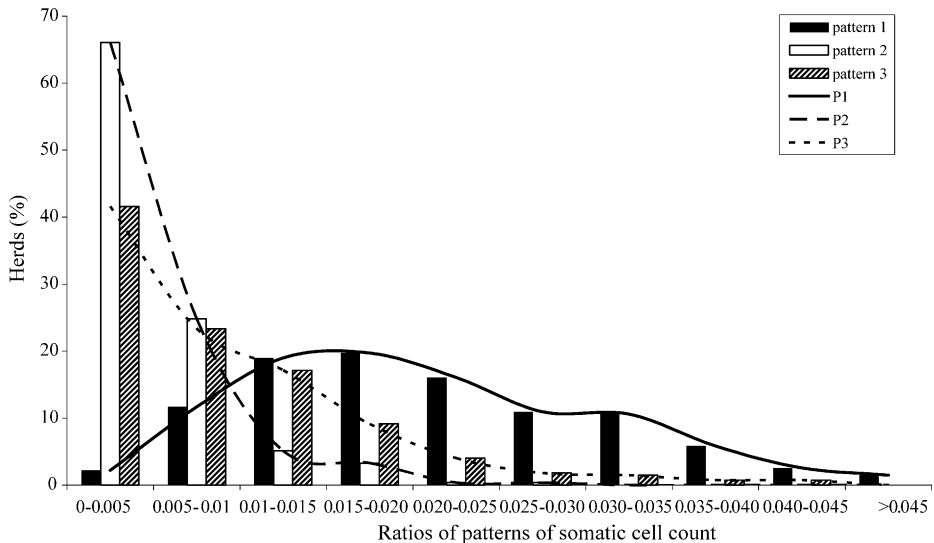


Fig. 1. Distribution of three SCC patterns in 274 herds, in The Netherlands, 1992–1993.

Table 1  
Distribution of mastitis, SCC patterns, and SCC parameters in 274 herds in The Netherlands, 1992–1993

	No. of cases	Mean	Upper limit of incidence rate (%)				
			10	25	50	75	90
Mastitis outcomes <sup>a</sup>							
CM	5719	0.0006	0.0002	0.0003	0.0005	0.0008	0.0011
ENV_CM	1561	0.0002	0.0000	0.0001	0.0002	0.0003	0.0005
CONT_CM	2681	0.0003	0.0001	0.0002	0.0003	0.0006	0.0009
SCC patterns <sup>b</sup>							
P1: quick recovery	2662	0.020	0.008	0.013	0.019	0.028	0.035
P2: slow recovery	361	0.004	0.000	0.000	0.003	0.006	0.009
P3: no recovery	860	0.009	0.000	0.003	0.007	0.012	0.019
P4: shorter no recovery	1082	0.011	0.000	0.004	0.009	0.015	0.022
P5: shortest no recovery	2353	0.019	0.006	0.010	0.018	0.025	0.033
SCC parameters <sup>c</sup>							
INF: new infections	12641	0.069	0.042	0.057	0.071	0.084	0.098
H_SCC: high SCC	41253	0.195	0.089	0.135	0.193	0.251	0.298

<sup>a</sup> Number of cases of clinical mastitis per cow-day at risk.

<sup>b</sup> See Section 2.4.2 for description of SCC patterns.

<sup>c</sup> See Section 2.4.3 for description of SCC parameters.

The Spearman rank-order correlations between SCC patterns and CM in Table 3 indicated that the strongest association for the incidence rate of CM was with the distribution of P1 (0.15); this was also true for ENV\_CM (0.19). The distribution of all three no recovery patterns were positively associated with the incidence rate of CONT\_CM.

The estimated associations between the currently used SCC parameters (INF and H\_SCC) and the incidence rate of CONT\_CM were higher than the associations with ENV\_CM (Table 3). The association of INF with the incidence rate of ENV\_CM was close to zero, and the association with H\_SCC was slightly negative (Table 3).

Table 2  
Spearman rank-order correlations between SCC patterns and SCC parameters (standard errors in parentheses) in 274 herds in The Netherlands, 1992–1993

	P1	P2	P3	P4	P5	INF
SCC patterns <sup>a</sup>						
Quick recovery (P1)						
Slow recovery (P2)	0.14 (0.06)					
No recovery (P3)	−0.03 (0.06)	0.15 (0.06)				
Shorter no recovery (P4)	0.03 (0.06)	0.17 (0.06)	0.85 (0.02)			
Shortest no recovery (P5)	0.31 (0.06)	0.10 (0.06)	0.65 (0.04)	0.74 (0.04)		
SCC parameters <sup>b</sup>						
New infections (INF)	0.29 (0.06)	0.24 (0.06)	0.36 (0.06)	0.44 (0.05)	0.50 (0.05)	
High SCC	0.07 (0.06)	0.20 (0.06)	0.63 (0.04)	0.70 (0.03)	0.71 (0.03)	0.76 (0.03)

<sup>a</sup> See Section 2.4.2 for description of SCC patterns.

<sup>b</sup> See Section 2.4.3 for description of SCC parameters.

Table 3

Spearman rank-order correlations between mastitis, SCC patterns and SCC parameters (standard errors in parentheses) in 274 herds in The Netherlands, 1992–1993

	Mastitis outcomes <sup>a</sup>		
	CM	ENV_CM	CONT_CM
<b>SCC patterns<sup>b</sup></b>			
Quick recovery	0.15 (0.06)	0.19 (0.06)	0.02 (0.06)
Slow recovery	0.04 (0.06)	0.01 (0.06)	0.04 (0.06)
No recovery	0.08 (0.06)	-0.06 (0.06)	0.13 (0.06)
Shorter no recovery	0.04 (0.06)	-0.03 (0.06)	0.17 (0.06)
Shortest no recovery	-0.00 (0.06)	-0.02 (0.06)	0.19 (0.06)
<b>SCC parameters<sup>c</sup></b>			
New infections	0.09 (0.06)	0.01 (0.06)	0.20 (0.06)
High SCC	0.01 (0.06)	-0.06 (0.06)	0.19 (0.06)

<sup>a</sup> Mastitis outcomes are the incidence rates of clinical mastitis (CM), CM associated with environmental pathogens (ENV\_CM) and CM associated with contagious pathogens (CONT\_CM).

<sup>b</sup> See Section 2.4.2 for description of SCC patterns.

<sup>c</sup> See Section 2.4.2 for description of SCC parameters.

In general, combined information on the distributions of both the quick recovery and shortest no recovery pattern seemed to be informative for CM, ENV\_CM and CONT\_CM. The vertical ‘bars’ in Fig. 2 show that the incidence rate of overall CM was increasing with increasing values of P1 (x-axis), but not when P5 was increasing (y-axis). Similarly, the highest incidence rate of ENV\_CM was estimated when P1 was high (Fig. 3).

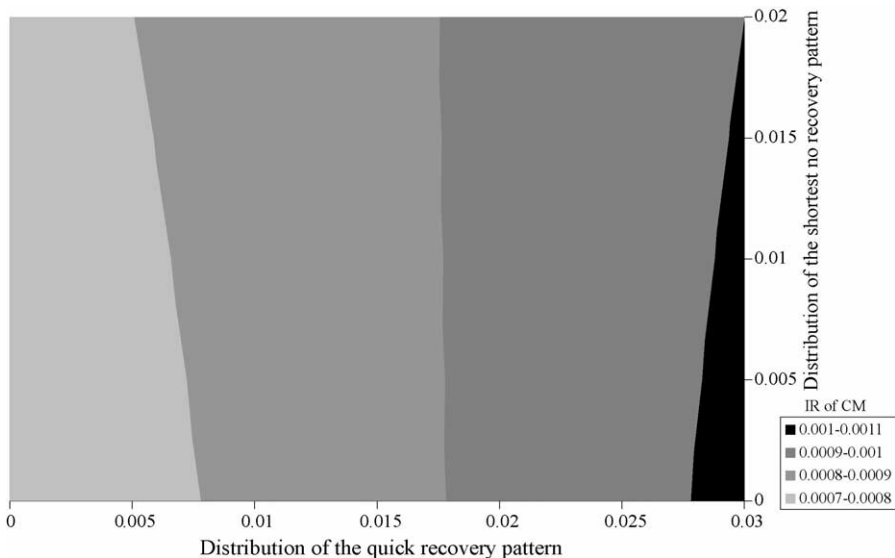


Fig. 2. Incidence rates of overall clinical mastitis vs. spline functions (and their interaction) for the distribution of the quick recovery pattern and the distribution of the shortest no recovery pattern. Data from 274 herds in The Netherlands, 1992–1993, are used.



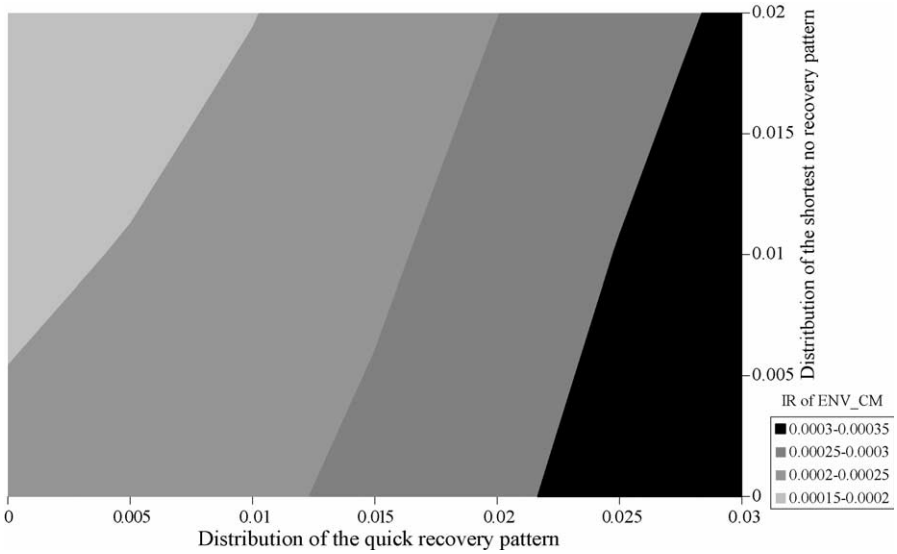


Fig. 3. Incidence rates of clinical mastitis associated with environmental pathogens vs. spline functions (and their interaction) for the distribution of the quick recovery pattern and the distribution of the shortest no recovery pattern. Data from 274 herds in The Netherlands, 1992–1993, are used.

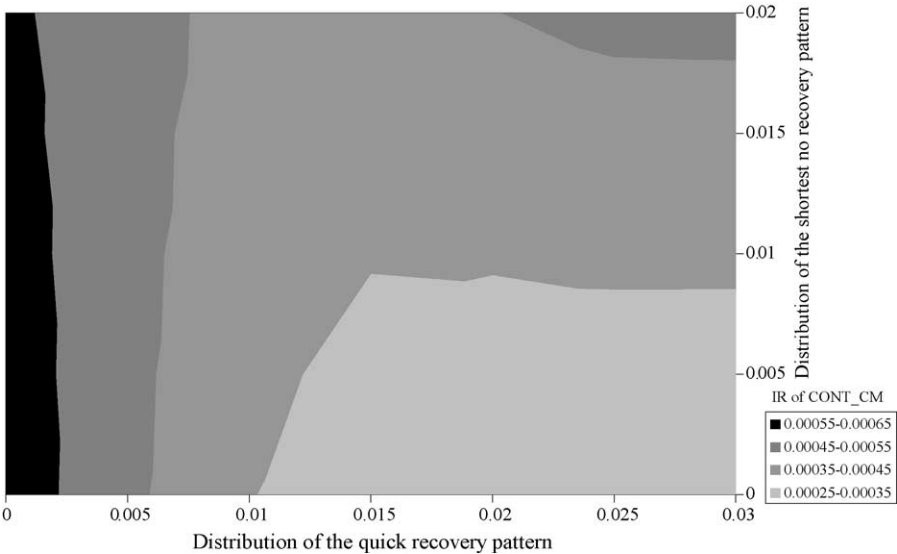


Fig. 4. Incidence rates of clinical mastitis associated with contagious pathogens vs. spline functions (and their interaction) for the distribution of the quick recovery pattern and the distribution of the shortest no recovery pattern. Data from 274 herds in The Netherlands, 1992–1993, are used.

Table 4

Odds ratios indicating the chance of being classified as one of the best (b) or worst (w) 25% of herds for occurrence of clinical mastitis (CM), CM associated with environmental pathogens (ENV\_CM), and CM associated with contagious pathogens (CONT\_CM)

	SCC patterns <sup>a</sup>				SCC parameters <sup>b</sup>			
	P1 (b)	P1 (w)	P5 (b)	P5 (w)	INF (b)	INF (w)	H_SCC (b)	H_SCC (w)
<b>Mastitis outcomes</b>								
CM (b)	1.7	0.4	1.5	0.5	2.5*	0.8	1.6	1.1
CM (w)	0.8	2.5*	0.9	1.1	0.6	1.1	0.7	0.7
ENV_CM (b)	1.8*	0.6	0.8	1.0	1.3	0.9	1.0	1.1
ENV_CM (w)	0.6	2.1*	1.4	0.9	1.1	0.8	1.2	0.4*
CONT_CM (b)	1.5	0.4*	1.7	0.5*	2.5*	0.6	1.8*	0.7
CONT_CM (w)	1.4	1.2	0.6	1.8	0.7	1.4	0.4*	1.4

Predictors were classified in the best (b) or worst (w) 25% of the herds with respect to the quick or shortest no recovery distributions and of the current SCC parameters.

<sup>a</sup> P1: quick recovery pattern, P5: shortest no recovery pattern.

<sup>b</sup> INF: new infections, H\_SCC: test-day recordings of SCC >250,000 cells/ml.

\* Significantly different from 1, at  $p < 0.05$ .

However, Fig. 4 shows that occurrences of CONT\_CM mainly seemed to be indicated by an absence of P1, and to a lesser extent by the presence of P5, because the highest incidence rate of CONT\_CM was estimated when P1 was very low. Therefore, a high frequency of P1 could be associated with high incidences rates of CM and ENV\_CM, and a low frequency of P1 with high incidence rates of CONT\_CM. The results shown in Figs. 2–4 correspond with the estimated correlations in Table 3 between the quick recovery and shortest no recovery pattern and CM, ENV\_CM and CONT\_CM.

A herd classified in the upper quartile of the P1 distribution had 2.5 times more chance to belong to the upper quartile for CM as well (Table 4). When a herd belonged to the lower quartile for P1, it had a 2.1 times higher chance to be classified as a herd in the upper quartile for ENV\_CM, and, in contrast, a reduced chance to be classified as a herd with a high incidence of CONT\_CM (OR = 0.4). A herd with a high presence of P5 had a low chance of being classified in the lowest quartile for CONT\_CM (OR = 0.5).

The OR for the current SCC parameters indicate that they better distinguish between the 25% best and worst herds with respect to CONT\_CM than with respect to ENV\_CM. A herd with a low proportion of test-day recordings of SCC >250,000 cells/ml had a high chance of being classified in the lowest quartile for CONT\_CM (OR = 1.8).

#### 4. Discussion

Before starting a mastitis control program, it is important to first analyse the herd situation. The current SCC parameters are: (1) bulk milk somatic cell count (BMSCC); (2) percentage of cows with H\_SCC; (3) percentage of cows with INF; and (4) culling rate because of mastitis. Additionally, evaluation of the distribution of mastitis-causing pathogens can be informative. However, in 1997 only approximately 10% of the herds sampled cases of subclinical mastitis on a regular basis, and cases of CM were even less

frequently sampled in The Netherlands (Sampimon, 1997). As a result, information on bacteriological sampling is unfortunately not often present. The results in the current study, however, indicate that the presence of patterns of SCC provide information on the incidence of both CONT\_CM and ENV\_CM. The major advantage of using SCC patterns is that since test-day recordings of SCC are freely available to all farmers that use SCC recording, a knowledge of SCC patterns may facilitate the implementation of pathogen-specific mastitis control programs, and our results are discussed against this background.

#### *4.1. Comparison of SCC patterns with current SCC parameters*

The estimated correlations in the current study show that the distribution of the current SCC parameters are mainly indicative of CONT\_CM status, but not so much for ENV\_CM. This is in agreement with earlier statements that the standard mastitis control program is successful in decreasing the prevalence of intramammary infections with contagious pathogens, but less successful in preventing new cases of CM with environmental pathogens (Hillerton et al., 1995). However, patterns in SCC seem to provide information on both CONT\_CM and ENV\_CM. Namely, the distribution of the quick recovery pattern is more strongly correlated to the incidence rate of ENV\_CM than the current SCC parameters. Furthermore, the correlation between the distribution of the shortest no recovery pattern and CONT\_CM is similar to those between the current SCC parameters and CONT\_CM. Therefore, information on the distribution of a combination of SCC patterns might indicate the occurrences of both CONT\_CM and ENV\_CM.

In the current study, it is shown that occurrences of ENV\_CM are mainly indicated by the presence of quick recovery patterns, and to a lesser extent by the absence of no recovery patterns. This was expected, since cases of ENV\_CM are typically acute cases (Vaarst and Enevoldsen, 1997). On the other hand, occurrences of CONT\_CM seem to be mainly indicated by an absence of the quick recovery pattern, and to a lesser extent by the presence of the shortest no recovery pattern. One explanation could be that cases of CONT\_CM are often characterised by a long duration and high SCC (Sears et al., 1990; Daley et al., 1991), and therefore, the presence of quick recovery patterns is unlikely.

Because of the definition of the no recovery SCC patterns, a cow with P5, will also have a P4 and P3 recorded. This overlap in the definitions causes strong correlations between P3, P4 and P5. Therefore, that herds that are ranked high for one of the no recovery patterns, are also ranked high for the other no recovery patterns. This is also the reason why the distribution of any of the three no recovery patterns are all equally informative at ranking the herds for the occurrence of CONT\_CM.

#### *4.2. Application of SCC patterns*

Based on the mean distribution of SCC patterns in a herd, the necessity to introduce pathogen-specific mastitis control programs in a herd, consisting of adequate guidelines to control the predominant type of mastitis, can be determined. To be able to present adequate mastitis control guidelines, it is necessary to have an overview of all test-day recordings of SCC in a herd. Besides, comparing herds, classifying them in the upper or lower quartile of

the herds, might be informative. Progress might, therefore, be obtained when the patterns in SCC are applied by national milk recording systems, because it is relatively easy for them to provide an overview on each test-day of the patterns in a herd. Improvement of the possibilities for using the information for management advice, might be achieved by publishing the patterns in SCC for heifers and older cows separately. Differences in the patterns in SCC around a case of pathogen-specific CM between heifers and older cows were shown in an earlier study (De Haas et al., 2002b). An even further optimisation might be achieved by publishing only the distribution of SCC patterns in early lactation as 90% of most pathogen-specific cases of CM have occurred before 200 DIM (De Haas et al., 2002b). Therefore, analysing only the first part of the lactation might increase the information in distribution of SCC patterns as they are expected to occur around the cases of CM. Furthermore, it might be worthwhile to look at other definitions of SCC patterns. For example, analysing SCC and CM as two traits that are continuous over time and using a variance and covariance matrix to describe the association between variation in SCC and incidence of CM. However, to investigate this, an even more advanced technique (like a random regression model) has to be implemented. With random regression test-day models, deviations from the standard curve are analysed. These deviations from the standard curve can then be specified more precisely as either the rate of increase or decrease in SCC, or the slope of increase or decrease in SCC. These two parameters are derivations of either the first or second half of the SCC patterns, and therefore, the patterns investigated in the current study are a foretaste for quantitative parameters of SCC to be defined in further studies.

## **5. Conclusions**

The major advantage of using patterns in SCC, over bacteriological culture of cases of CM, is that they are freely available to all farmers that use SCC recording. Information on both the quick recovery and shortest no recovery pattern could therefore easily be included in mastitis control programs that aim to capture the full scope of environmental and contagious mastitis-causing pathogens. However, it should be kept in mind that the division of pathogens into environmental and contagious is not absolute. Next to the ability to distinguish between environmental and contagious mastitis, the SCC patterns provide additional information on, for example (spontaneous or therapeutic) cure. This suggests that patterns in SCC are useful as basic tools for health management advice. Based on the distribution of SCC patterns, the necessity to introduce pathogen-specific mastitis control programs can be determined.

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