Development and application of a monitoring system to estimate clinical mastitis in cattle herds using routinely collected data

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Abstract

The aim of this study was i) to evaluate whether it is possible to monitor clinical mastitis incidence (CMI) on routinely collected herd data and ii) to develop a yearly monitoring system 'MastitisMonitor' for clinical mastitis (CM).

In 2013, farmers recordings of CM and routine herd data were collected from 227 dairy herds. The herd data consisted of identification and registration records, antimicrobial usage, milk control records, bulk milk (BM) SCC data and bacteriological results of BM samples. Data from 2/3 of the herds was used to develop a model to predict the CMI per 100 cows per year. The model results were validated on the data from the remaining 1/3 of the herds. The best model contained 11 variables and estimated a CMI per 100 cows per year of 32.5 cases, while the farmers registered 33.4 cases.

As a next step, the model was used to predict and monitor the CMI per 100 cows per year for 15,170 dairy herds in the Netherland in the period 2012-2015. The results showed a slight decrease in CMI in time from on average 32.9 cases in 2012 to 29.8 cases per 100 cows per year in 2015. Furthermore, a seasonal trend in CMI was observed with highest values in winter and summer. Hence, the MastitisMonitor (i) provides information on CMI without the need of labour intensive recording of CM cases and (ii) provides a benchmark for farmers which can motivate farmers to continuously improve udder health in their herds.

Keywords: *clinical mastitis, monitoring, dairy cattle, predictive modeling, herd data*

Introduction

Clinical mastitis (CM) is a frequently occurring, economical important disease for dairy industries around the world (1). Subclinical mastitis is often monitored based on individual or BM SCC data, however a good recording system of CM is often not available. Nevertheless, clinical mastitis incidence (CMI) is an important indicator for both animal health and welfare. Monitoring CMI, provides insight in the trend in time and enables early detection of unfavourable alterations.

Until recently, farmers had to observe and record all cases of CM in the herd for a year, to enable estimation of CMI. This is very labor intensive and thus costly. Therefore, there was a need for a more cost-efficient method to estimate and monitor CMI.

An increasing amount of herd health information such as usage of an automatic milking system for intramammary and dry cow treatment, grazing management, milk production, herd size, animal movements, age and parity is routinely collected from dairy herds. These data were available for analysis and might be related to CMI.

The aim of this study was to evaluate the possibility to use routine herd data to estimate the CMI and to develop a monitoring system 'MastitisMonitor' in which the CMI can be monitored on a seasonal basis for the population of Dutch dairy herds.

Material and methods

Using routine herd data to predict clinical mastitis

In this study, 227 dairy herds with a manual milking system that were member of a milk control program participated. The farmers from these herds observed, registered and communicated all CM cases in their herd to GD Animal Health (GD) on a monthly basis from January 1st to December 31st 2013. After each month the farmers were asked to send in forms with the identification numbers from cows diagnosed with CM, the quarters in which an abnormality was observed, the date on which CM was observed and whether or not the cases were treated with antibiotics. Farmers used an uniform definition of CM i.e. every abnormality of udder and/or milk observed by the farmer (1). Abnormalities included alteration in color or consistence of the milk, swollen or red quarters and clinical signs in cows such as depression, anorexia, dehydration or fever (2). For each herd, the CMI was subsequently calculated as the number of quarter cases of CM divided by the number of cow days at risk (DAR) multiplied by 365 days and 100 cows.

Besides the CM data, the following routinely collected herd data were available from the participating herds: Identification and registration records, milk recording data (calving, parity, individual SCC records), BM SCC records, antimicrobial usage data at the herd level and monthly bacteriological results of BM samples.

The CMI at the herd level were combined with the collected routine herd data and the 227 herds were randomly assigned to one of two sub-populations to either develop the prediction model (data from 156 herds) or validate the developed model (data from 71 herds) (3). A generalised estimating equation population average model with a normal distribution, an independent correlation structure and an identity link function in Stata 13® (4) was used. The CMI observed by the farmer for each herd in each season was the dependent variable and all parameters from the routine herd data were evaluated based on their added values to the fit and the predictive capabilities of the model (5). Thereafter, the data from the 71 remaining herds were used to validate the ability of the model to predict the CMI. Based on a post estimation linear prediction in Stata, the CMI was predicted for each of the validation herds. Both the observed and predicted CMI were combined for all herds and compared, both seasonal and year level, to evaluate whether the model was capable of accurately predicting the CMI for all dairy herds.

Development of the "MastitisMonitor"
Data collection organisations were requested for permission to use their routinely collected herd data for the estimation of the CMI per 100 cows per year for the complete dairy sector in the Netherlands. To assure confidentiality, all data were anonymised prior to its usage by an external firm (IntoFocus Data Transformation Services). The variables that might link the data back to the original source were encrypted and the same encryption code was used for all datasets, to ensure that all data could be combined for analysis. Consent was provided to use the routine data from 15,170 dairy herds (85% of the Dutch dairy population).

The parameters that were included in the final model were calculated for all dairy herds. Based on the parameter results i) the CMI per 100 cows per year estimated for each season and year and ii) the trend in time (moving average) was estimated for the period between January 2012 and December 2015. In addition, as part of the "MastisMonitor" the results from the most recent period were compared to the prior period and changes in the model parameters were evaluated.

Results

Prediction of CMI for all Dairy Herds Based on Routinely Collected Data: In total, 26,762 cows in the 227 dairy herds that participated in the development of the prediction model, were at risk for developing CM. CM cases were observed 6,656 times in 4,874 different milking cows. In the whole study population, the median CMI was 27.8 cases per 100 cows per year and the mean CMI was slightly higher with 32.1 cases per 100 cows per year.

The model contained 11 parameters (table 1) and predicted an average CMI of 32.5 (95% CI: 30.2-34.8) per 100 cows per year based on the observations from the 71 validation herds. The CMI observed by the farmers was not significantly different with a CMI of 33.4 (95% CI: 29.5-37.4).

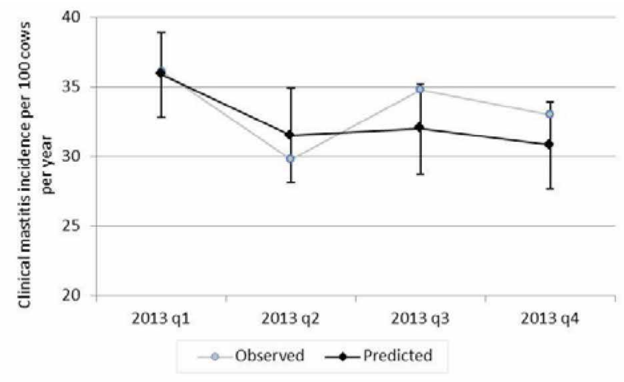
Table 1. Parameters in the optimal predictive model for clinical mastitis incidence rate (CMI) per 100 cows at risk

Types of data	Parameters
Antimicrobial usage	Animal Daily Dose (ADD) of antibiotics for intramammary treatment, ADD of antibiotics for parenteral treatment in cows ≥2 years, Total ADD of antibiotics in cows ≥2 years
Milk recording data	Percentage primiparous cows with a SCC >150 x 10^3cells/ml, Percentage multiparous cows with a SCC >250 x 10^3 cells/ml, Percentage multiparous cows with an increased SCC >250 x 10^3cells/ml
Identification and registration data	Herd size, growth in herd size
Other	Season, BM SCC

The calibration plot showed that the average trend line for the validation herds was very close to the optimal 45° line.

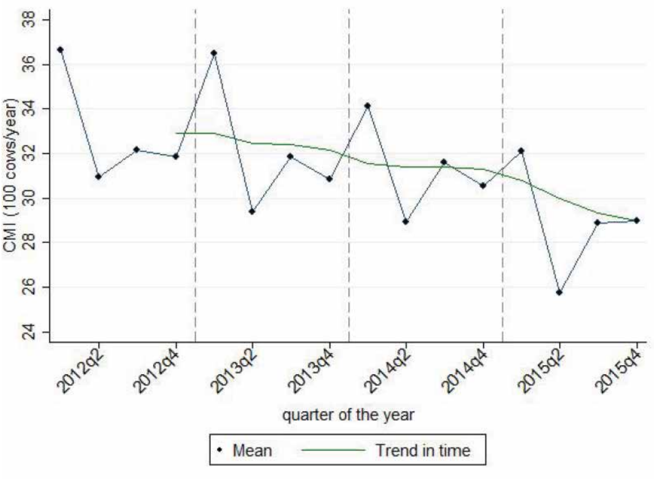
The ability of the model to predict extreme high CMI values was limited, possibly because some key predictor variables were not available in the data that were assessed. On seasonal level, the predicted and observed CMI were very similar based on the validation dataset (Figure 1).

Figure 1. Mean and 95% confidence interval of the CMI per 100 cows per year for 71 Dutch dairy herds, used for validation.



Monitoring CMI in the dairy sector: "MastitisMonitor"
Between 2012 and 2015, the CMI was estimated at 31.4 cases per 100 cows per year (median 30.8). At the individual herd level, the predicted CMI roughly varied between 9.4 (1st percentile) and 58.4 (99th percentile). During the analysed period, a slight decrease in CMI was observed from on average 32.9 cases per 100 cows per year in 2012 to an average CMI of 29.8 in 2015 (Figure 2).

Figure 2. Mean CMI per 100 cows per year for each season and trend in time between January 2012 and December 2015 for 15,170 Dutch dairy herds.



The decreasing trend is associated with a decline in animal daily dose of antibiotics for intramammary treatment, a decrease in BM SCC and a decrease in udder health parameters that were based on individual SCC measurements.

A seasonal trend was visible with the highest predicted CMI values in winter and summer and lowest CMI in spring of each year (Figure 2).

Discussion

With this study we showed that it is possible to predict the average CMI for all dairy herds in a country based on routine herd data. To our knowledge, this is the first time an attempt has been made to predict CMI on routinely collected data. Prediction models are commonly used in human medicine (6) and genetic modeling (7). In many countries, herd data are routinely collected because of cattle improvement schemes, milk quality control, regulations and surveillance. This provide opportunities to apply predictive modeling related to animal health and diseases. The developed model accurately estimated the CMI, which was not significantly different from the average CMI that was observed and registered by the farmers. Nevertheless, the model has some limitations in correctly predicting extreme values of CMI at farm level.

It is not clear whether the parameter estimates are also valid for dairy herds with an automatic milking system (AMS) and for dairy herds outside the Netherlands. When developing the model, it was decided to exclude farms with an automatic milking system because CM detection in these herds differs substantially from CM detection in herds with a conventional milking system. Therefore, the distribution of the model predictors might differ substantially between dairy herds with a conventional versus an automatic milking system and might also differ between dairy industries in different countries. In the Netherlands, approximately 15% of the dairy herds use an AMS and it was recommended to validate the developed model for dairy herds with an AMS. At this moment a group of 90 Dutch dairy farmers with an AMS are observing and registering all CM cases in their herds to optimise the MastitisMonitor model for AMS herds.

Observing and recording CM by the farmer remains a crucial source of information in dairy management. This requires a large amount of discipline and is not always feasible. This study showed that monitoring CM in the Dutch dairy industry based on routine data provides a good alternative for large scale, expensive field studies. It is, however, advisable to revalidate the developed models after the first few years because there are some major alterations going on in the dairy industry such as disappearance of the European quota system for milk production and the resulting increase in herd size, which might influence the predictive value of a model based on routine data.

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