A PRACTICAL EVALUATION OF MILK CONDUCTIVITY MEASUREMENTS

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SUMMARY

The milk electrical conductivity of 31 cows milked with a Liberty automatic milking system was monitored for 15 weeks. An alert triggered when conductivity rose by 17.5% corresponded with a rise in cell count to more than 400,000 cells/ml. When a trigger equivalent to a cell count rise to more than 200,000 cells/ml was applied then the sensitivity for mastitis detection was 80% and the specificity was 63%. When milk samples were analysed for pathogenic bacteria then the rate of false positive triggers was 12%.

INTRODUCTION

Mastitis results in changes in the electrical conductivity of milk, primarily because of changes in the concentration of sodium, potassium and chloride ions. Measurement of conductivity can therefore assist in the early identification of mastitis. Equipment is commercially available for the in-line measurement of milk conductivity but currently there are no agreed guidelines on how best to use this information to maximise the sensitivity and specificity of these measurements. Milk conductivity values can show substantial variation in the absence of mastitis due to factors such as stage of lactation, milking interval and oestrus (1). These non mastitis factors complicate the interpretation of conductivity changes and the accurate selection of cows for early antibiotic therapy. There is currently a desire to reduce total antibiotic use, improve the targeting of antibiotic used and improve the bacteriological cure of udder infections. Early identification of mastitis using changes in electrical conductivity and early antibiotic intervention has been shown to be an efficient method of achieving a bacteriological cure in cows infected experimentally with Streptococcus uberis (2). Early identification and treatment of mastitis has the potential to improve the efficacy of treatment, improve bacteriological cure rate and hence reduce recurrence rates and potentially overall antibiotic usage per cow. A recent field study was undertaken by ADAS Bridgets and the Institute for Animal Health to evaluate individual quarter conductivity and its relation to somatic cell count (SCC) and mastitis.

OBJECTIVE

Evaluation of individual quarter conductivity and its relation to somatic cell count and mastitis
MATERIALS AND METHODS

Data were collected from 31 Holstein cows in a 70 cow herd for a period of 15 weeks between November 1999 and February 2000. Cows were milked through a two-box Liberty automatic milking unit that had the facility to monitor conductivity changes on an individual quarter basis. The system was set to record increases in conductivity of 10% or more when compared to the mean of that quarter over the previous 14 milkings. Milk yield, milking interval and days in milk were collected at each milking and analysed on a whole cow basis, somatic cell count samples were collected weekly and analysed on an individual quarter basis and bacteriology samples were collected from 35 quarters following a conductivity trigger and were also analysed on an individual quarter basis. All data were collated to give weekly means resulting in a total of 465 ‘cow-weeks’ of data for whole cow values or a maximum of 1600 ‘quarter-weeks’ of data for individual quarter values.

RESULTS

Occurrence of conductivity triggers

Over the recording period 194 cow-weeks (42%) had one or more quarter conductivity triggers, 271 (58%) had no trigger. The overall occurrence of conductivity triggers by cow-week is summarised in Table 1.

| Table 1. Frequency of conductivity triggers by week of study |
|---------------------------------|-----|-----|-----|-----|-----|
|                                | Week 0 | Week 1 | Week 2 | Week 3 or 4 | Total 1 or more |
|                                |       |       |       |             | cow-weeks       |
| Weeks 1-15                     | 271 (58%) | 83 (18%) | 68 (15%) | 43 (9%)     | 194 (42%)       | 465               |

Assessed on a quarter-week basis, 310 quarter-weeks (20%) had a conductivity trigger of 10% or more, while 1229 quarter-weeks (80%) had no trigger.

Somatic cell count and occurrence of conductivity triggers

The geometric mean SCC was significantly higher for quarter-weeks in which there was a conductivity trigger than for quarter-weeks with no trigger (P<0.001). This is summarised in Table 2.
Table 2. Mean log SCC for quarter-weeks with and without conductivity trigger

<table>
<thead>
<tr>
<th>Occurrence of conductivity trigger</th>
<th>Geometric mean SCC</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>3.52 (34)</td>
<td>0.044</td>
</tr>
<tr>
<td>Yes</td>
<td>5.28 (196)</td>
<td>0.087</td>
</tr>
</tbody>
</table>

Figure 1. Trend in geometric mean SCC at increasing conductivity trigger percentages

Geometric mean SCC at increasing conductivity trigger percentage

The geometric mean SCC was significantly higher for quarter-weeks with a greater increase in conductivity (P<0.001). The geometric mean SCC was lowest for quarter-weeks with no conductivity trigger, SCC increased as the conductivity trigger percentage increased from 10% to 20%. This is illustrated in Fig. 1. The numbers shown above the histogram bars indicate the number of quarter-weeks in each conductivity band category. With the exception of the small number of quarter-weeks with a conductivity trigger in excess of 30%, quarter-weeks in conductivity trigger bands greater than 17.5% had a mean SCC in excess of 400,000 cells/ml.

Estimation of sensitivity and specificity

Each quarter-week was categorised as uninfected, with a SCC ≤ 200/000 cells/ml, or infected, with a SCC >200,000/ml, and then this was related to the percentage of quarter-weeks which had a conductivity trigger of 10% or more. This is summarised in Table 3.
Table 3. Estimation of false positive and false negative conductivity triggers (SCC at 200,000/ml)

<table>
<thead>
<tr>
<th>Conductivity trigger</th>
<th>Quarter SCC ≤ 200,000 cells/ml (%)</th>
<th>Quarter SCC &gt;200,000 cells/ml (%)</th>
<th>Total numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>None (&lt;10%)</td>
<td>1080 (70.2)</td>
<td>149 (9.7)</td>
<td>1229 (80)</td>
</tr>
<tr>
<td>10% or more</td>
<td>162 (10.5)</td>
<td>148 (9.6)</td>
<td>310 (20)</td>
</tr>
<tr>
<td>Total numbers</td>
<td>1242 (81)</td>
<td>297 (19)</td>
<td>1539 (100)</td>
</tr>
</tbody>
</table>

Just below 10 percent of quarter-weeks had no conductivity trigger but had a SCC of more than 200,000 cells/ml and were, therefore, described as false negatives. Just over 10 percent of quarter-weeks with a conductivity trigger of 10% or more had a SCC of less than 200,000 cells/ml and were described as false positives. From these data the sensitivity was calculated to be 50 percent and the specificity 87 percent. The positive predictive value was calculated to be 48 percent and the negative predictive value to be 88 percent.

Bacteriology

Over a period of 14 weeks, 35 quarter samples were submitted for bacteriology. Of these samples, nine were later discarded being classed as repeat samples from quarters that had previously been sampled and had the same pathogen isolated. Of the remaining 26 samples, 24 had a SCC of more than 200,000 cells/ml, 16 revealed major mastitis causing pathogens and eight samples contained mixed growths or contaminants making positive identification of the mastitis causing pathogen impossible. Two samples contained no pathogens. Overall, three of the samples (12%) were categorised as being false positives. All three had a SCC of below 400,000 cells/ml (42,000, 116,000 and 353,000 cells/ml) and none had mastitis pathogens identified.

Milk yield and occurrence of conductivity triggers

Cow-weeks with no conductivity trigger had a significantly higher mean milk yield compared to cow-weeks with one or multiple quarter triggers (P<0.001). This is illustrated in Table 4.

Milking interval and occurrence of conductivity triggers

There was a significant difference in milking interval between cow-weeks with zero, one or multiple quarter conductivity triggers (P=0.01). Although no clear pattern occurred, there was a trend for cows with one quarter (8.7 h), two quarters (9.2 h) or three or four quarters (8.3 h) triggered to have a longer milking interval than those with no quarter triggers (8.4 h).
Table 4. Milk yield/milking for cow-weeks with no, one or multiple quarter conductivity triggers

<table>
<thead>
<tr>
<th>Number of quarters/cow triggered</th>
<th>Mean milk yield (kg/milking)</th>
<th>SEM</th>
<th>Number of cow-weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>8.4</td>
<td>0.16</td>
<td>228</td>
</tr>
<tr>
<td>1</td>
<td>7.7</td>
<td>0.27</td>
<td>83</td>
</tr>
<tr>
<td>2</td>
<td>7.4</td>
<td>0.29</td>
<td>68</td>
</tr>
<tr>
<td>3+</td>
<td>6.6</td>
<td>0.37</td>
<td>43</td>
</tr>
<tr>
<td>P</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
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</tbody>
</table>

DISCUSSION

Identifying high risk quarters as those with a 10% or greater increase in milk electrical conductivity compared to the mean conductivity of the previous 14 milkings resulted in 20% of quarter-weeks and 42% of cow-weeks being triggered. As the conductivity trigger increased above 10% the geometric mean SCC also increased.

To make use of conductivity changes in the early detection of mastitis a high level of sensitivity and specificity is desirable to avoid ‘missing’ infected cows or treating uninfected cows unnecessarily. A quarter SCC of 200,000 cells/ml was used as the divide between infected and uninfected quarters, as recommended by the International Dairy Federation (3). Using these criteria the data indicated a specificity of 87% but a sensitivity of only 50% suggesting that under this system only a relatively small percentage (13%) of uninfected cows would be wrongly identified and treated unnecessarily but an unacceptable percentage (50%) of infected cows (SCC>200,000/ml) would be missed. It has been reported (1) that at low conductivity trigger thresholds the frequency of false positives was high (low specificity) and that even with high sensitivity and specificity, a high level of false positives can occur if the prevalence of clinical mastitis is very low (4). The positive predictive value, which expresses the probability that the quarter with a positive conductivity trigger is infected, was 48% while the negative predictive value, which expresses the probability that a quarter with no conductivity trigger is not infected, was 88%. The assessment made from the small subset of bacteriology samples, however, suggests that 88% of conductivity triggers were associated with either a raised SCC or the presence of mastitis causing pathogens or both and it can be concluded that the quarters sampled for bacteriology were not representative of the whole population of study cows.
Milk yield and milking interval were both significantly different in cow-weeks with conductivity triggers and agree with the trends reported in earlier research. Conductivity has been reported as being higher in cows with longer intervals between milkings (5) and typically cows in early lactation (higher yields) have lower milk conductivity than cows towards the end of lactation (6).

CONCLUSIONS

Over a 3-month period, 42% of cow-weeks and 20% of quarter-weeks had an increase in quarter conductivity of 10% or more compared to the mean quarter conductivity of the previous 14 milkings.

Geometric mean SCC was higher in quarter-weeks with a 10% plus increase in conductivity compared to quarters with a conductivity change of less than 10%.

When determined only on weekly SCC measurements the specificity of this system was estimated to be 87%, the sensitivity only 50%, the negative predictive value 88% and the positive predictive value only 48%.

The limited number of bacteriology samples indicated a higher specificity than that estimated with SCC data alone with the number of false positives being estimated to be only 12 percent.

ACKNOWLEDGEMENTS

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REFERENCES