Effect of Severity of Systemic Signs During the Acute Phase of Experimentally Induced "Escherichia coli" Mastitis on Milk Production Losses

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ABSTRACT

The objectives were to describe the systemic signs during the acute phase of experimental "Escherichia coli" mastitis and to relate these with losses in milk production during the reconvalescent period. Eleven cows, 20 to 30 d postpartum, were inoculated with 10^4 cfu of E. coli 0157 in rear quarters. Heart rate, rectal temperature, frequency and amplitude of rumen contractions, plasma Zn and Fe concentrations, and counts of E. coli were used to monitor severity of disease during the acute phase. Areas under curves of clinical parameters, plasma Zn and Fe concentrations, and counts of E. coli were calculated during 36, 120, and 125 h postinoculation, respectively. Areas under curves of milk production were calculated during 21 d postinoculation. Losses in total daily milk production were related positively with areas under curves of heart rate, rumen amplitude, counts of E. coli in secreta from inoculated quarters, and plasma Zn and Fe concentrations. These parameters may prove suitable to establish an accurate prognosis for returning to milk production cows suffering from acute or peracute E. coli mastitis and to evaluate efficacy of drugs in experimental mastitis. (Key words: Escherichia coli, mastitis, milk losses)

INTRODUCTION

"Escherichia coli" mastitis is an important cause of morbidity and losses in milk production (MP) in dairy cows and, therefore, has become of great economic importance to the dairy industry (2). Most cases of acute or peracute E. coli mastitis occur from calving to peak lactation (2, 17, 19). Hill et al. (8, 9, 10) suggested that the more severe disease course of E. coli mastitis in early lactation is due to a delay in mobilization rate of neutrophils into the udder, resulting in failure to eliminate E. coli from the infected quarters.

Systemic clinical signs that are often observed during acute E. coli mastitis include: general depression, anorexia, fever, decreased frequency and amplitude of rumen contractions, and a marked decrease in MP, not only in the infected quarters but also in the adjacent unaffected ones (2, 16, 23). The hematologic changes include leukopenia, followed by leukocytosis, and a decrease in plasma Zn and Fe concentrations (16, 21, 23).

Acute or peracute E. coli mastitis is one of the most serious challenges facing dairy practitioners. Even if the animal survives, it is often difficult to give an accurate prognosis on rate of return to normal function in the current and subsequent lactations. Several studies have indicated that losses in MP during the reconvalescent period of E. coli mastitis are positively related to the severity of systemic signs during the acute phase (8, 10, 21). Quantitation of correlations between systemic clinical signs and MP would allow for a more accurate prediction of the changes to return to MP in the current lactation of cows suffering from acute or peracute E. coli mastitis. Moreover, these parameters may be of use to evaluate efficacy of drugs in experimental mastitis. The objectives of this study were to describe systemic clinical signs,
plasma Zn and Fe concentrations, and counts of E. coli in secretions from inoculated quarters during the acute phase of experimental E. coli mastitis, and to relate these parameters with losses in MP during the convalescent period.

**MATERIALS AND METHODS**

**Animals**

Eleven clinically healthy, crossbred Holstein × Dutch Friesian cows in lactation 1 to 8 were used. All animals had calved normally and had no history of retained placenta, mastitis, or periparturient disease. Cows were 20 to 30 d postpartum. They were kept in a tie-stall barn and fed wilted grass silage and concentrate based on milk production. Water was provided for ad libitum access. Cows were milked at 0730 and 1530 h. At 7, 4, and 2 d; and at 24 and 1 h before inoculation, the udder was examined clinically, and quarter foremilk samples of all cows were obtained for bacteriological examination (18) and electronic somatic cell counting (Model F, Coulter Electronics, UK) (11).

**Inoculum**

An encapsulated strain of E. coli 0157 isolated from a case of clinical mastitis was used for intramammary inoculation. The strain was maintained on nutrient agar CM 3 (Oxoid Ltd., Basingstoke, UK) at 4°C. Prior to the experiments the organisms were subcultured in brain-heart infusion broth CM 225 (Oxoid, Basingstoke, Hampshire, UK) and grown at 37°C. The culture was washed three times and diluted in saline to yield approximately 5 × 10^8 cfu/ml. Inoculum size was 20 ml of the diluted culture. Numbers of E. coli in inocula were determined in each experiment using plate count method (1) on violet red bile glucose agar (VRBG) CM 485 (Oxoid) after 18 to 24 h of incubation at 37°C. Actual bacterial counts of the inoculum were 8.8 × 10^8 ± 1.3 × 10^8 cfu (Mean ± SEM).

**Experimental Procedures**

At the start of the experiment (1000 h or 2.5 h after the morning milking), 20 ml of pyrogen-free saline solution, containing approximately 10^8 cfu E. coli 0157 were infused in both rear quarters of all cows. Cows were not milked at the afternoon milking following inoculation. On the 7th d after inoculation, all cows received antibacterial treatment immediately after the morning milking (16).

Rectal temperatures and heart rates were determined every 30 min during the first 36 h postinoculation (16). Rumen motility was recorded continuously up to 36 h postinoculation (PI), as described (16). The frequency and amplitude of rumen contractions were calculated from the recordings over 30-min periods. Changes in clinical parameters were expressed as a percentage of baseline (preinoculation) values.

Quarter MP was measured twice daily with a four-quarter milking unit from 7 d before to 21 d after inoculation. Changes in total daily MP and daily MP in rear quarters after inoculation were expressed as a percentage of average baseline values of MP.

Blood samples were collected in vacutainer tubes (Venoject®, Terumo Corp., Tokyo, Jpn.) by caudal puncture of the jugular vein immediately prior to inoculation (baseline) and at 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 36, 48, 72, 96, and 120 h PI for determination of plasma Zn and Fe concentrations (20).

**Statistical Analysis**

Area under the curves (AUC) were calculated for clinical parameters (during 36 h PI), total daily MP, MP from rear quarters (during 21 d PI), plasma Zn and Fe concentrations (during 120 h PI), and bacterial counts of E. coli in left and right rear quarters (during 125 h PI). Changes of clinical signs, plasma Zn and Fe concentrations, and MP were expressed as percentage of baseline; change in rectal temperature was expressed in degrees Celsius; bacterial counts were expressed as 10^log of colony-
forming units. These data were graphed against time after inoculation. The AUC of each parameter was calculated for every cow as:

\[ \Sigma_i = (t_i - t_{i-1}) \times f_{i-1} + \{0.5 \times (t_i - t_{i-1}) \times (f_i - f_{i-1})\} \]

where:

- \( t_i \) = the time of observation,
- \( t_{i-1} \) = the previous time of observation,
- \( f_i \) = the value of parameter at time \( i \),
- \( f_{i-1} \) = the value of clinical parameter at time \( i-1 \), and
- \( f_0 \) = the mean of the values of the parameter before infection.

The predictive value of parameters during the acute phase of disease for losses in MP was tested in the general linear model using a commercial microcomputer package (Statistix®, NH Analytical Software, Roseville, MN):

\[ \text{AUC of MP} = a + b \times \text{parameter} + e \]

where:

- \( a \) = the general mean (intercept),
- \( b \) = the regression coefficient, and
- \( e \) = the error term, presumably normally distributed.

RESULTS

Clinical Signs and Milk Production Before Inoculation

Clinical signs before inoculation revealed no abnormalities. Mastitis pathogens were not demonstrated, and foremilk SCC were <250,000/ml. Average rectal temperature of the cows at the start of the experiment was 38.8°C (range 38.5 to 39.0°C), and average heart rate was 82 beats/min (range 68 to 92 beats/min). The characteristic powerful rumen contraction sequences occurred about once a minute. Milk production ranged from 16.8 to 31.7 L/d; average daily MP was 23.5 ± .44 L/d (mean ± SEM). The MP in rear quarters was 55.8 ± 1.8% of total daily MP. Mean plasma Zn concentrations were 15.8 mmol/L (range 11.0 to 19.0 mmol/L), plasma Fe concentrations averaged 19.2 mmol/L (range 12.0 to 29.0 mmol/L).

Clinical Signs, Milk Production, and Counts of Escherichia coli in Mastitis Secreta After Inoculation

A marked swelling of all inoculated quarters was observed from 3 to 4 h PI, and quarters were warm and painful. From 10 h PI, appearance of secretions varied widely from normal with some fine clots in animals with moderate clinical signs to yellowish serous secretions containing large clots in animals with severe clinical signs.

Data on heart rate, rectal temperature, and frequency and amplitude of rumen contractions, counts of \( E. \) coli in mastitis secreta, plasma Zn and Fe concentrations, and MP are in Table 1. A great variation in duration and severity of clinical signs was observed after inoculation of \( \pm 10^4 \) cfu of \( E. \) coli in both rear quarters. In general, induction of \( E. \) coli mastitis elicited fever, an increase in heart rate, and inhibition of rumen contractions (both frequency and amplitude). Rectal temperature started to increase from 6 h PI to maximum values of 41.6°C (range 41.0 to 42.0°C) at about 9 h PI. In three animals showing severe signs of disease, rectal temperatures remained at least 1°C above baseline values throughout the entire observation period and showed a second peak (2.1°C above baseline) from 24 to 29 h PI. Maximum increases in heart rate varied from 32.3 to 52.2% above baseline values from 8 to 12 h PI. Frequency and amplitude of rumen contractions started to decrease from 7 h PI; maximum decreases for rumen frequency and rumen amplitude were reached at 10 to 12 h PI and varied from 30.4 to 75%, and 38.2 to 85.4% below baseline, respectively. In 5 animals, clinical parameters returned to baseline values at 15 h PI and remained within preinoculation range during the remainder of the observation period; three other animals showed depression, anorexia, fever, tachycardia, and decreased rumen motility up to 36 h PI.

Counts of \( E. \) coli in secreta from left rear quarters initially increased in all cows. For cows with mild clinical symptoms, maximum counts were \( 3.3 \times 10^{10} \) cfu/ml at 12 h PI; in animals with severe clinical symptoms, maximum counts of \( 1.2 \times 10^{10} \) cfu/ml were reached at 18 h PI. Secreta of the former animals were bacterio-
TABLE 1. Changes in clinical parameters, counts of *Escherichia coli* in mastitis secreta, concentrations of Zn and Fe in plasma, and milk production (MP) in 11 cows with experimental *E. coli* mastitis.\(^1\)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>(\bar{X})</th>
<th>SEM</th>
<th>n(^3)</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate, %</td>
<td>11.83</td>
<td>.45</td>
<td>798</td>
<td>-19.0</td>
<td>51.0</td>
</tr>
<tr>
<td>Rectal temperature, °C</td>
<td>1.0</td>
<td>.04</td>
<td>798</td>
<td>-5</td>
<td>3.4</td>
</tr>
<tr>
<td>Rumen frequency, %</td>
<td>-18.85</td>
<td>.66</td>
<td>801</td>
<td>-75.00</td>
<td>33.33</td>
</tr>
<tr>
<td>Rumen amplitude, %</td>
<td>-29.83</td>
<td>1.02</td>
<td>801</td>
<td>-85.84</td>
<td>31.31</td>
</tr>
<tr>
<td>Counts of <em>E. coli</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right quarter, log(_{10})</td>
<td>2.83</td>
<td>.53</td>
<td>171</td>
<td>-3</td>
<td>9.1</td>
</tr>
<tr>
<td>Left quarter, log(_{10})</td>
<td>3.08</td>
<td>.19</td>
<td>171</td>
<td>-3</td>
<td>9.0</td>
</tr>
<tr>
<td>Total daily MP, %</td>
<td>-26.1</td>
<td>2.1</td>
<td>231</td>
<td>-99.0</td>
<td>16.7</td>
</tr>
<tr>
<td>Daily MP in rear quarters</td>
<td>-40.2</td>
<td>2.4</td>
<td>228</td>
<td>-100.0</td>
<td>17.7</td>
</tr>
<tr>
<td>Plasma Fe, %</td>
<td>-33.52</td>
<td>2.29</td>
<td>196</td>
<td>-86.67</td>
<td>60.00</td>
</tr>
<tr>
<td>Plasma Zn, %</td>
<td>-33.48</td>
<td>2.79</td>
<td>196</td>
<td>-93.33</td>
<td>35.71</td>
</tr>
</tbody>
</table>

1Rear quarters of all cows were inoculated with \(10^4\) cfu of *E. coli* 0157.

2Clinical signs were recorded during 36 hours postinoculation (PI); counts of *E. coli* were determined up to 125 h PI; concentrations of Zn and Fe in plasma up to 120 h PI; milk production was recorded during 21 d PI.

3Number of observations.

4Changes are expressed as a percentage below (-), or above preinoculation values.

Logically negative after 29 h PI, whereas secreta of the latter contained large numbers of *E. coli* (\(>1,000\) cfu/ml) at all samplings up to 125 h PI. These animals showed the most severe disease course and greatest losses in MP.

Overall mean decrease in total daily MP during 21 d after inoculation was 26.10% below baseline (Table 1); for MP in rear quarters overall decrease was 40.15% below baseline. All cows showed a clear drop in MP during the first days following inoculation. Three cows with mild clinical symptoms during the acute phase regained preinoculation MP within 1 wk. One cow failed to produce milk in all quarters from 4 d PI; 2 cows went dry in rear quarters from 5 d PI.

Concentrations of Zn in plasma started to decrease from 6 h PI; a plateau of low Zn concentrations (64.3 to 93.7% below baseline) was observed from 15 to 24 h PI. Plasma Fe concentrations decreased from 9 h PI and a plateau of low Fe (57.1 to 86.7% below baseline) occurred from 18 to 36 h PI. In 3 cows showing severe systemic signs, concentrations of Zn and Fe in plasma remained low up to 72 h PI.

### Correlations Between Clinical Signs, Bacterial Counts in Secreta from Inoculated Quarters, and Concentrations of Iron and Zinc in Plasma

Areas under curves were calculated for clinical parameters during 36 h PI for counts of *E. coli* during 125 h PI, and for plasma Fe and Zn concentrations up to 120 h PI. After inoculation of *E. coli*, heart rate, rectal temperature, and counts of *E. coli* increased; rumen motility, Zn and Fe concentrations in plasma, and MP decreased (Table 1). The AUC of heart rate, rectal temperature, and counts of *E. coli* were >0 if values of these parameters were above baseline; the AUC of Zn and Fe concentrations in plasma were >0 if values of these parameters were below baseline. Correlations were calculated for each pair of the mentioned parameters (Table 2). The AUC of numbers of *E. coli* in secreta from inoculated quarters were related positively with AUC of heart rate, rectal temperature, rumen frequency, rumen amplitude, and Zn and Fe concentrations in plasma. The AUC of Zn and Fe concentrations in plasma correlated positively with AUC of heart rate, rectal temperature, rumen frequency, and rumen amplitude. The AUC of heart rate temperature showed positive correlations with AUC of rumen frequency (\(r=0.607\); \(P<0.05\)) and rumen amplitude (\(r=0.855\); \(P<0.001\)) but was not significantly related to heart rate. The AUC of rumen frequency and rumen amplitude showed positive correlations (\(r=0.762\); \(P<0.01\)). Positive correlations were also observed between AUC of plasma Zn and Fe concentrations (\(r=0.914\); \(P<0.001\)) and between AUC of counts of *E. coli* in secreta from left and right rear quarters (\(r=0.868\); \(P<0.001\)).
TABLE 2. Correlation coefficients between clinical parameters, counts of Escherichia coli in mastitis secreta, and Fe and Zn concentrations in plasma in 11 cows following inoculation of $10^6$ E. coli in rear quarters.

<table>
<thead>
<tr>
<th>AUC of</th>
<th>Heart rate</th>
<th>Rectal temperature</th>
<th>Rumen frequency</th>
<th>Rumen amplitude</th>
<th>Counts of E. coli</th>
<th>Plasma</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Left</td>
<td></td>
</tr>
<tr>
<td>Heart rate</td>
<td>.520</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rectal temperature</td>
<td></td>
<td>.607*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rumen frequency</td>
<td>.762**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rumen amplitude</td>
<td>.832***</td>
<td>.855***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Counts of E. coli</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>.55</td>
<td>.617*</td>
<td>.41</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>.762**</td>
<td>.710**</td>
<td>.600*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plasma Zn</td>
<td>.748**</td>
<td>.719**</td>
<td>.780**</td>
<td>.870***</td>
<td>.69*</td>
<td>.879***</td>
</tr>
<tr>
<td>Plasma Fe</td>
<td>.607*</td>
<td>.600*</td>
<td>.747***</td>
<td>.720**</td>
<td>.553</td>
<td>.715**</td>
</tr>
</tbody>
</table>

1 Clinical symptoms were recorded during 36 h postinoculation; counts of E. coli in secreta from inoculated quarters, and concentrations of Zn and Fe in plasma were determined up to 125 and up to 120 h after inoculation, respectively. From these data, areas under curves (AUC) were calculated.

*P<.05.

**P<.01.

***P<.001.

Regression of Clinical Signs, Bacterial Counts in Secreta from Inoculated Quarters, and Zinc and Iron Concentrations in Plasma on Milk Production

Areas under curves of total daily MP and MP in rear quarters were calculated from milk production data during 21 d PI. Regressions of AUC of clinical and hematologic parameters and counts of E. coli on AUC of MP are in Table 3 and Figures 1 and 2. Areas under curves of total daily MP was positively related with AUC of heart rate (P<.05), counts of E. coli in secreta from inoculated quarters (P<.001), rumen amplitude (P<.01), and Zn (P<.01) and Fe concentrations in plasma (P<.05) (Table 3, Figure 1). Milk production from rear quarters showed similar relationships with these parameters but was also positively related (P<.05) with rectal temperature (Table 3, Figure 2). The AUC of total daily MP in rear quarters of 11 cows were inoculated with $10^6$ cfu of E. coli 0157.

TABLE 3. Regressions of areas under curves (AUC) of clinical symptoms, concentrations of Zn and Fe in plasma and counts of Escherichia coli in secreta from inoculated quarters on milk production (MP) in inoculated quarters and total daily MP.

<table>
<thead>
<tr>
<th>AUC of</th>
<th>AUC of total MP$^2$</th>
<th>AUC of MP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P</td>
<td>b</td>
</tr>
<tr>
<td>Heart rate</td>
<td>-38.87</td>
<td>1.37</td>
</tr>
<tr>
<td>Rectal temperature</td>
<td>-27.18</td>
<td>15.69</td>
</tr>
<tr>
<td>Rumen frequency</td>
<td>119.14</td>
<td>.99</td>
</tr>
<tr>
<td>Rumen amplitude</td>
<td>-173.81</td>
<td>.67</td>
</tr>
<tr>
<td>Counts of E. coli:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left quarter</td>
<td>-396.41</td>
<td>2.55</td>
</tr>
<tr>
<td>Right quarter</td>
<td>-129.79</td>
<td>2.31</td>
</tr>
<tr>
<td>Plasma Zn</td>
<td>268.37</td>
<td>.14</td>
</tr>
<tr>
<td>Plasma Fe</td>
<td>74.70</td>
<td>.17</td>
</tr>
</tbody>
</table>

1 Rear quarters of 11 cows were inoculated with $10^6$ cfu of E. coli 0157.

2 Milk production was recorded during 21 d after inoculation, and expressed as percentage from pre-inoculation values; from these data AUC were calculated.

3I = Intercept; b = regression coefficient.
Figure 1. Regressions of area under curves (AUC) of heart rate (HR), rumen amplitude (RA), plasma Zn concentrations (Zn), and counts of *Escherichia coli* in secretions from left rear (Clr) and right rear quarters (Crr) on losses in total daily milk production (MPt) in 11 cows inoculated with 10⁶ *E. coli* O157 in rear quarters. Heart rate and RA were monitored during 36 h postinoculation (PI); MPt during 21 d PI; and Fe and Zn during 120 h PI. Clr and Crr were recorded during 125 h PI. From these data AUC were calculated.
Figure 2. Regressions of areas under curves (AUC) of heart rate (HR), rumen amplitude (RA), plasma Zn concentrations (Zn), and counts of *Escherichia coli* in secreta from left rear (Clr) and right rear quarters (Crr) on losses in daily milk production in rear quarters (MPr) in 11 cows, inoculated with $10^4$ cfu of *E. coli* 0157 in rear quarters. Heart rate and RA were monitored during 36 h postinoculation (PI); MPr during 21 d PI, and Fe and Zn during 120 h PI. Clr and Crr were recorded during 125 h PI. From these data AUC were calculated.
quarters showed a positive correlation with AUC of total daily MP ($r=0.959; \ P<0.0001$).

**DISCUSSION**

Results indicate that numbers of *E. coli* in secreta from inoculated quarters were positively correlated with severity of systemic clinical signs and decreases of plasma Zn and Fe concentrations during the acute phase (Table 2). It is generally accepted that systemic clinical signs and decreased Zn and Fe concentrations in plasma during *E. coli* mastitis are primarily initiated by cell products of *E. coli*, especially endotoxin (23). Results of previous studies (13, 14, 23) indicated that systemic signs and decreases of Zn and Fe in plasma during endotoxin-induced mastitis are probably not mediated by the absorption of endotoxin from the udder. The generation and subsequent release into the blood circulation of unknown endogenous inflammatory mediators from the udder probably is responsible for systemic signs of disease during *E. coli* mastitis. Intramammary infusion of endotoxin does not result in decreased rumen motility in contrast to experimental or field cases of *E. coli* mastitis (23). Moreover, it seems likely that other cell products, released during active growth of *E. coli*, are involved in the pathogenesis of *E. coli* mastitis (5, 6).

The AUC of rumen amplitude and rumen frequency were positively related with AUC of rectal temperature (Table 2), which may be explained by the fact that both fever and decrease in rumen motility during *E. coli* mastitis are at least partly mediated by a mechanism involving prostaglandins (15). The AUC of Zn and Fe concentrations in plasma were positively related with AUC of heart rate, rectal temperature, and rumen motility (Table 2). Decreases of Zn and Fe concentrations in plasma are components of a constellation of host responses collectively referred to as the acute phase response (4). This response can be initiated by a variety of endogenus or exogenus insults (3, 4). Decreases in Zn and Fe concentrations in plasma in endotoxin-induced mastitis proved to be predominantly dose-dependent; with increasing doses of endotoxin, the peak effect was more pronounced and the duration of the effect was protracted (22). In our experiments, we observed that the AUC of Zn and Fe concentrations in plasma were highly correlated with numbers of *E. coli* in secreta from inoculated quarters. It seems likely that this relationship is physiological, since fever and reduced Fe are commonly regarded as an important part of the nonspecific defense mechanism of the host against invading pathogenic bacteria (12).

The AUC of daily milk production from rear quarters and total daily milk production during 3 wk after inoculation were positively related with AUC of counts of *E. coli* in secreta from inoculated quarters up to 125 h after inoculation (Table 3, Figures 1 and 2). This means that cows with high numbers of *E. coli* in secreta from infected quarters showed greatest losses in MP. Losses in MP in cows suffering from *E. coli* mastitis are attributed both to systemic signs of disease and to local pathophysiological disturbances within the infected quarters that eventually lead to diminished secretory activity (5, 6). In our study, three cows that showed severe systemic signs up to 70 h after inoculation were completely dried off in rear quarters. The secretory tissue in infected and uninfected quarters of cows with hyperacute *E. coli* mastitis start to develop histopathological changes reminiscent of normal mammary gland involution if systemic signs persist longer than 4 d (5, 9). This may explain the great losses in milk production observed in some of the cows. In our experiments, MP was measured during 3 wk after inoculation and, therefore, it is not possible to give a long-term prognosis for MP. A retrospective study (7) to determine the prognosis of cows with peracute or acute coliform mastitis showed that, in 59% of the affected cows, quarters returned to a milk-like secretion within approximately 1 mo after infection. If a cow did not return to milk production during that lactation and was kept in the herd, she had a 50% chance of recovery to MP in that quarter the following lactation. Losses in MP during 3 wk PI were highly related to some clinical, hematologic, and bacteriological parameters during the acute phase of *E. coli* mastitis (Table 3, Figures 1 and 2). Heart rate, amplitude of rumen contractions, Zn and Fe concentrations in plasma, and counts of *E. coli* in secreta from infected quarters may prove suitable to establish an accurate prognosis for returning to MP in the current lactation of cows suffering from acute or peracute *E. coli* mastitis. Moreover, these parameters may be of use to evaluate the
efficacy of drugs in experimental mastitis. Naturally, the value of these parameters depends on the observation period used. For instance, in preinoculation values at the last sampling (120 h PI). However, concentrations of zinc in plasma of these cows at 120 h PI were closer to preinoculation values. This probably explains the higher correlation between Zn concentrations in plasma and MP as compared with concentrations of Fe in plasma and MP. Therefore, the prognostic value of plasma Fe concentrations can probably be increased by longer sampling period. Studies are needed to evaluate the long-term prognostic value of these parameters in field cases of acute or peracute *Escherichia coli* mastitis.

**ACKNOWLEDGMENTS**

The authors are grateful to W. Kremer and T. Cruysen for excellent technical assistance and to F. van Mosel for his handling and care of the animals.

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