

THE EFFECTS OF DURATION OF RETAINED PLACENTA ON REPRODUCTION,
MILK PRODUCTION, POSTPARTUM DISEASE AND CULLING RATE

T. van Werven,¹ Y.H. Schukken,¹ J. Lloyd,² A. Brand,¹
H.Tj. Heeringa¹ and M. Shea²

¹Department of Herd Health and Reproduction, State University of
Utrecht, Yalelaan 7, 3584 CL Utrecht, the Netherlands

²Department of Large Animal Clinical Sciences,
Michigan State University, East Lansing, MI 48824, USA

Received for publication: *July 5, 1991*

Accepted: *April 15, 1992*

ABSTRACT

The effects of various durations of placental retention (6, 8, 12, 23, 47 and 71 hours) on reproductive performance, milk production, postpartum disease and culling rate were measured to determine a definition of retained placenta. Data from 1010 calvings on 21 commercial Dutch dairy herds were analyzed by parity groups.

The reproductive performance of first calf heifers and of second and third parity cows was not significantly affected by the duration of placental retention. However, fourth parity and higher cows showed the best reproductive performance when they expelled their placenta within 6 hours. Retention of the placenta for longer than 6 hours resulted in an increase of 17 days to the first service and 26 additional days open. Older cows showed decreased milk production with an increase in the duration of retention. For first calf heifers there was no cut-off point at which delayed expulsion of the placenta became detrimental to overall performance. Second and third parity cows as well as fourth parity and higher cows demonstrated the highest overall performance in all the parameters tested when they expelled their placentas within 6 hours after parturition.

Key words: retained placenta, reproductive performance, milk production, culling, dairy cattle

INTRODUCTION

The incidence and effects of retained placenta on reproductive performance and milk production have been investigated by many authors. However, the effects of retained placenta on subsequent reproductive performance and milk production continue to be a controversial issue. Some authors report reduced fertility among cows with retained placenta (1-5), but there are several authors which indicate that retained placenta does not significantly alter fertility (6-8). Reports of the effect of retained placenta on milk production show similar diversity. A positive effect (8) of placental retention on the milk production has been reported; however, other studies report no significant effect of retained placenta on milk production (1,2,4).

To date, there does not appear to be a consistent definition of retained placenta in cattle. Retained placenta has been variously defined as failure to expel the placenta

within 8 to 12 hours (2), within 12 hours (1), within 24 hours (6-10) and within 48 hours (3) postpartum. In still other reports, a definition of retained placenta is not given (4, 11-15). Theoretically, all cows that calve have retained placenta because there is always a period of time between parturition and expulsion of the placenta. Thus it is only the number of hours that determines the definition of retained placenta. We therefor designed this study 1) to make an inventory of the duration of placental retention, and 2) to establish the effects of duration of placental retention on reproductive performance, milk production, postpartum disease and culling rate.

MATERIALS AND METHODS

Source of Data

Data were collected from 21 dairy farms enrolled in a herd health program of the Department of Herd Health and Reproduction, Veterinary College, University of Utrecht. Farm visits were conducted at 3- to 4-week intervals. The data were collected from the records kept by owners and from veterinary records collected during the farm visits. The main breeds of cows in the study were Dutch Friesians and Dutch and Holstein Friesian crosses. One herd consisted of Meuse-Rhine-Yssel cattle. All farms had free-stall housing except for one that had a tie-stall system. The mean herd size was 56.2 cows (SD 19.6), with mean milk production of 8054.0 kg (SD 887.1). The average fat and protein contents of the milk were 4.0% and 3.3%, respectively. All calvings (n = 1087) between December 1, 1988, and March 1, 1990, were recorded, and the cows' performances were followed up through October 1, 1990.

Description of Data

The time between parturition and expulsion of the placenta was recorded for each calving. If the duration of retained placenta was less than 24 hours, the owner recorded the time in hours; if the duration was more than 23 hours the time was recorded in days. Calvings were excluded if the duration of the retained placenta was missing (n=77). Three fertility parameters were examined: interval from calving to first service, conception rate at first service, and interval from calving to conception (days open).

Conception was based on veterinary pregnancy examination. Diagnoses of lochiometra (acute postpartum endometritis), endometritis, cystic ovaries, milk fever and displaced abomasum were made by clinicians. Mastitis diagnoses were made by either the owner or the veterinarian. Only the cases of mastitis that occurred in the first week of lactation were analyzed for the effect of retained placenta on mastitis (16). Lochiometra was defined as vulvar discharge observed within 2 weeks post partum. Vulvar discharge noted after 2 weeks post partum was defined as endometritis. Cystic ovaries included follicular cysts and luteal cysts; a displaced abomasum included both left and right displacements.

The interval from calving to the first service, days open, and milk production were continuous variables. All the other outcome variables were dichotomous (yes/no).

Data Analysis

The number of days that the placenta was retained were converted into hours of retention. Time periods of 6, 8, 12, 23, 47 and 71 hours were selected for duration of the retained placenta. Time periods of 8, 12, 23 and 47 hours were based on the most

commonly used definitions of retained placenta by other authors. The 6-hour period was based on the frequency distribution of duration of retention. The 71-hour period was based on the current definition of retained placenta at Michigan State University. Each time period, was used in turn as a definition of retained placenta. For each duration, the data were divided into 2 groups, one with a retention duration less than or equal to the time period (nonretention group) and one with a retention duration longer than the time period (retention group).

Since the incidence of retained placenta (4,7-9), fertility, milk production, postpartum disease and culling rate vary with age (7,8,13), the cows were classified as either first calf heifers and second or third parity cows and fourth parity or higher cows. Data were analyzed separately for each parity group and for each duration of placental retention, and the results of the nonretention group and the retention group were compared. The statistical significance level was chosen at $P \leq 0.05$. The means of continuous outcome variables were analyzed by an independent t-test and the dichotomous variables by the chi-square test. Finally, analysis of variance and logistic regression were performed, respectively, for the continuous and dichotomous dependent variables, to control for herd influence.

The general model for analysis of variance was

$$Y_{i,j,k} = \mu + RP_i + Herd_j + Par_k + e_{i,j,k}$$

where:

- $Y_{i,j,k}$ = dependent variable (observation of the k^{th} cow)
- μ = overall mean
- RP_i = effect of i^{th} time period of retention
- $Herd_j$ = effect of j^{th} herd ($j = \# \text{ herds} - 1$)
- Par_k = effect of k^{th} parity
- $e_{i,j,k}$ = error term

The logistic regression (the CATMOD procedure in SAS) used the same independent variables. The dependent variables had values of 0 or 1, where 1 denoted the occurrence of the outcome and 0 the nonoccurrence.

RESULTS

A frequency distribution of hours of placental retention within 25 hours after calving is shown in Figure 1. Figure 2 shows the distribution of retained placenta in days, beginning at Day 1. As well the mode as the median are at 6 hours, which may be suggestive of a physiological time range for expulsion of the placenta. Within 6 hours after calving, almost 66% of the cows expelled their placentas. Comparing the different parity groups we found that 73% of the first calf heifers, 67% of second and third parity cows, and 59% of the fourth and higher parity expelled their placentas within 6 hours.

The incidence rate of retained placenta was strongly influenced by the duration of placental retention and by parity (Table 1). Incidence rates decreased with duration of retention and increased with parity.

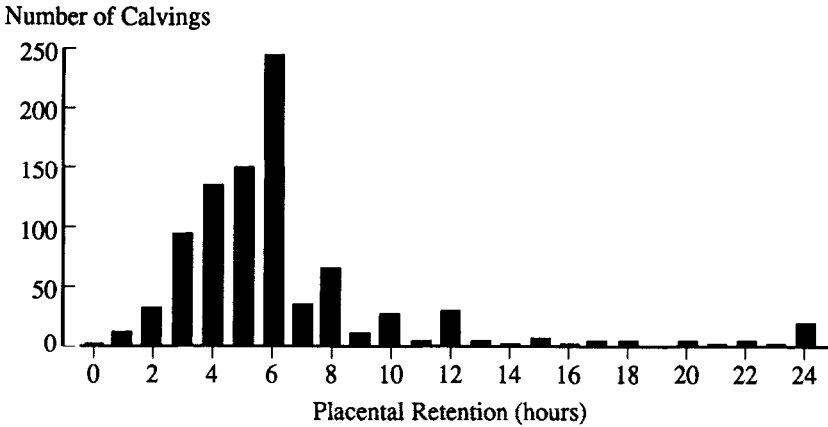


Figure 1. Numbers of calvings with placental retention of less than 25 hours. Data obtained from 871 calvings between December 1, 1988, and March 1, 1990.

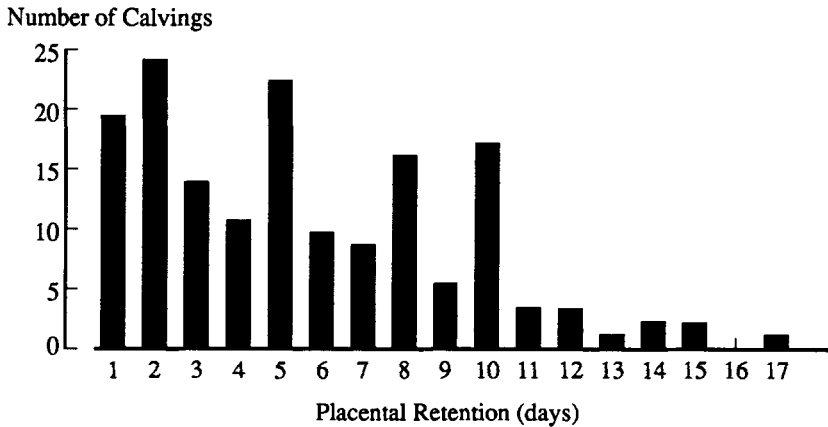


Figure 2. Numbers of calvings with placental retention more than or equal to 1 day. Data obtained from 157 calvings between December 1, 1988, and March 1, 1990.

First Calf Heifers

There were no significant differences in reproductive performance between the different durations of placental retention for first calf heifers (Table 2). The interval from calving to first service, days open, and conception rate at first service showed no important differences among the various durations. Relative risk (incidence rate retained placenta / incidence rate non retained placenta) for developing lochiometra in the different durations groups increased with the length of placental retention (Figure 3). Relative risk for developing endometritis was less than 1 in the 6-, 8-, 12- and 23-hour groups. This means that heifers without retained placenta had a higher incidence rate of endometritis than heifers with retained placenta.

Milk production of first calf heifers at 100 days postpartum showed significant differences in the 8, 12, and 23 hour groups after controlling for herd influences (Table 3). Rates of culling were significantly different only in the 72 hour group. More heifers in the non retained placenta groups of 6, 8 and 12 hour were culled for fertility reasons than in the retained placenta groups, but these differences were not significant. None of the first calf heifers acquired milk fever or displaced abomasum. Incidence rates of mastitis, observed one week after calving, showed significant differences in the 6 hour group. There was no effect of retained placenta on the incidence rate of cystic ovaries.

Table 1. The incidence rate of retained placenta per 100 calvings after various placental retention durations

Durations of placental retention (hours)	Parity			
	1 (n=277)	2 and 3 (n=394)	> 3 (n=339)	All (n=1010)
> 6	27.1	32.9	41.3	34.2
> 8	16.1	25.6	30.1	24.6
> 12	10.1	19.5	28.1	17.7
> 23	7.6	17.0	18.3	14.9
> 47	6.9	14.4	16.5	13.1
> 71	6.5	13.7	14.2	11.9

Table 2. Reproductive performance for first calf heifers after various durations of placental retention^a

Placental retention (hours)	n	First service		Days to conception
		Mean days post partum (n=237)	Conception rate	Mean days post partum (n=209)
≤ 6	202	79	47.1	109
> 6	75	76	47.6	113
≤ 8	232	78	48.0	110
> 8	45	78	42.9	109
≤ 12	249	78	47.4	110
> 12	28	78	45.5	112
≤ 23	256	78	47.7	110
> 23	21	79	41.2	115
≤ 47	258	78	47.7	110
> 47	19	76	40.0	107
≤ 71	259	78	47.7	110
> 71	18	76	40.0	107

^a Retention ≤ the time period is considered to be the nonretention group and retention > time period the placental retention group.

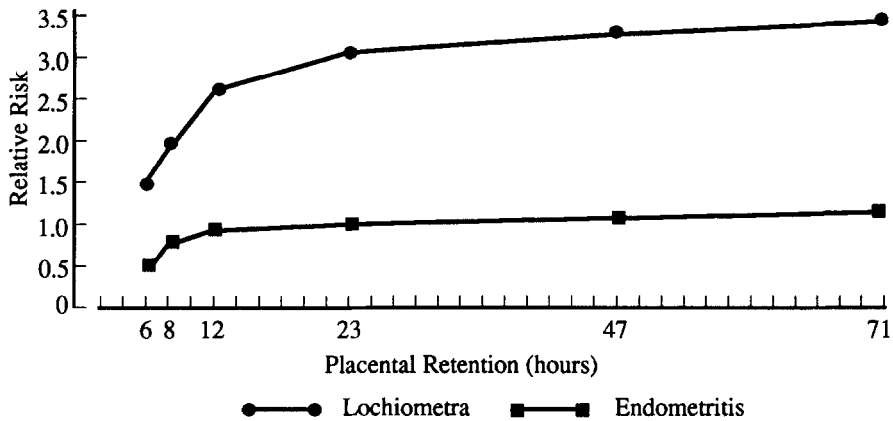


Figure 3. Relative risk of first calf heifers developing lochiometra (n=52) and endometritis (n=54) after various durations of placental retention. Data obtained from 277 calvings between December 1, 1988, and March 1, 1990.

Table 3. Milk production, culling rate and postpartum disease for first calf heifers after various durations of placental retention ^a

Placental retention (hours)	n	Milk production (kg)	Culling rate		Post partum disease
		100 days post partum (n=241)	Culling rate (%)	Fertility ^b (%)	Mastitis (first week) (%)
≤ 6	202	2399.9	22.8	19.6	3.5*
> 6	75	2308.9	28.0	9.5	9.3
≤ 8	232	2400.1**	22.0	17.6	3.9
> 8	45	2232.9	35.6	12.5	11.1
≤ 12	249	2398.8*	23.7	16.9	4.8
> 12	28	2161.4	28.6	12.5	7.1
≤ 23	256	2389.9*	23.8	16.4	5.0
> 23	21	2192.2	28.6	16.7	4.8
≤ 47	258	2387.9	23.6	16.4	4.7
> 47	19	2195.5	31.6	16.7	5.3
≤ 71	259	2387.9	23.9*	16.1	5.0
> 71	18	2195.5	27.8	20.0	5.6

^a Retention ≤ the time period is considered to be the nonretention group and retention > time period the placental retention group.

^b Percentage of culled cows that was culled for fertility reasons.

* P < 0.05. ** P < 0.01.

Second and Third Parity Cows

There were no significant differences in reproductive performance within the different duration groups for second and third parity cows (Table 4). Days from calving to first service, and days open were almost identical for all groups. Incidence rates for lochiometra and endometritis were significantly different within all groups. Relative risks for developing endometritis was the same for the 6- and 8-hour groups and then increased slightly with increasing duration of retention (Figure 4).

Cumulative 100-day milk production showed significant differences in all the retention duration groups. Milk production decreased slightly with increased duration of retained placenta (Table 5). Culling rates did not show significant differences by duration of retention, but more cows with retained placenta for the 47- and 71-hour groups were culled for fertility reasons. The incidence rate of milk fever increased with duration of retained placenta but was not significant ($P > 0.05$). The incidence of mastitis within a week after calving, showed significant differences within the 47- and 71-hour groups. Only 1 cow acquired a displaced abomasum. The incidence rate of cystic ovaries varied from 4.5 to 8.6 but showed no trends.

Table 4. Reproductive performance for second and third parity cows after various durations of placental retention ^a

Placental retention (hours)	n	First service		Days to conception
		Mean days post partum (n=355)	Conception rate	Mean days post partum (n=315)
≤ 6	265	75	43.7	106
> 6	130	77	41.3	115
≤ 8	294	75	44.5	107
> 8	101	76	41.5	112
≤ 12	318	76	44.0	108
> 12	77	75	42.9	109
≤ 23	328	76	44.2	108
> 23	67	73	41.5	109
≤ 47	338	76	45.0	108
> 47	57	70	43.9	109
≤ 71	341	76	44.7	108
> 71	54	72	36.6	110

^a Retention ≤ the time period is considered to be the nonretention group and retention > time period the placental retention group.

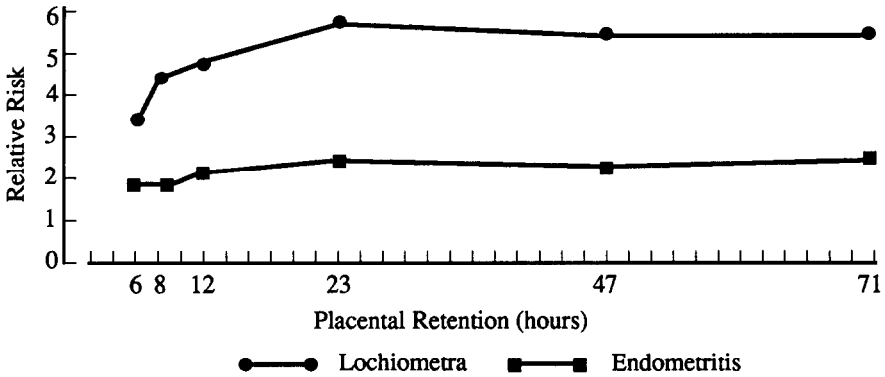


Figure 4. Relative risk of second and third parity cows developing lochiometra (n=50) and endometritis (n=58) after various durations of placental retention. Data obtained from 394 calvings between December 1, 1988, and March 1, 1990.

Table 5. Milk production, culling rate and postpartum disease for second and third parity cows after various durations of placental retention ^a

Placental retention (hours)	n	Milk production (kg)	Culling		Disease	
		100 days post partum (n=369)	Culling rate (%)	Fertility ^b (%)	Milk fever (%)	Mastitis rate (first week) (%)
≤ 6	265	3256.3*	17.7	29.8	2.3	4.3
> 6	130	3112.1	23.1	36.7	8.5	6.2
≤ 8	294	3251.2**	17.7	32.7	2.7	4.4
> 8	101	3080.9	24.8	32.0	8.9	5.9
≤ 12	318	3248.0**	18.5	30.5	2.8	4.1
> 12	77	3048.0	23.4	38.9	10.4	7.8
≤ 23	328	3240.7**	18.0	30.5	3.0	4.0
> 23	67	3052.4	26.9	38.9	10.4	8.9
≤ 47	338	3237.0*	17.8	30.0*	3.3	3.8*
> 47	57	3038.4	29.8	41.1	10.5	10.5
≤ 71	241	3238.1**	17.9	29.5*	3.5	3.8**
> 71	54	3026.6	29.6	43.8	9.3	11.1

^a Retention ≤ the time period is considered to be the non placental retention group and retention > time period the placental retention group.

^b Percentage of culled cows that was culled for fertility reasons.

* P < 0.05. ** P < 0.01.

Fourth and Higher Parity Cows

For cows with a fourth or higher parity we found an increase in the days to first service and days open with an increase in the duration of retained placenta (Table 6). For cows with retained placenta for 6 or less hours the days to first service and days open were, respectively, 17 and 26 days shorter than for cows with a placental retention for more than 6 hours. Conception rates at the first service did not show significant differences within time groups, but showed a trend for lower conception rates with longer duration of placental retention. Incidence rates of lochiometra and endometritis were significantly different for all the duration periods. Cows that had retained placenta for 6 or less hours were the least at risk for developing lochiometra and endometritis (Figure 5).

Cumulative 100-day milk production decreased with increased duration of retained placenta (Table 7). The differences within the time groups were significant after correction for various herd production levels. In the 6- and 8-hour duration groups culling rates of cows without retained placenta were higher than for cows with retained placenta ($P < 0.05$). The highest percentage of cows that was culled for fertility reasons was found for cows that had retained placenta for more than 71 hours. Incidence rates

Table 6. Reproductive performance for fourth and higher parity cows after various durations of placental retention ^a

Placental retention (hours)	n	First service		Days to conception
		Mean days post partum (n=273)	Conception rate	Mean days post partum (n=222)
≤ 6	199	71**	47.1	95**
> 6	140	88	40.5	121
≤ 8	237	74**	46.8	97**
> 8	102	87	38.8	125
≤ 12	244	76**	46.0	100**
> 12	95	88	38.2	125
≤ 23	277	76**	44.8	102*
> 23	62	89	37.5	122
≤ 47	283	76**	45.9	103*
> 47	56	89	35.7	124
≤ 71	291	76**	46.2	102*
> 71	48	90	33.3	128

^a Retention ≤ the time period is considered to be the nonretention group and retention > time period the placental retention group.

* $P < 0.05$.

** $P < 0.01$.

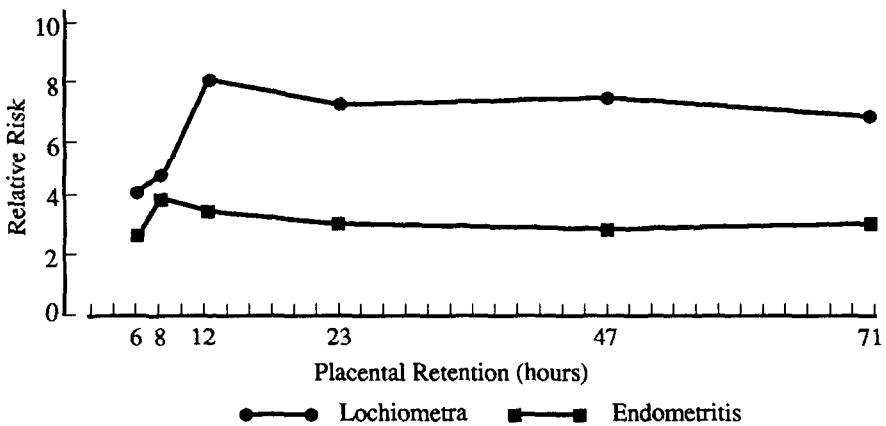


Figure 5. Relative risk of cows with parity 4 and higher developing lochiometra ($n=43$) and endometritis ($n=43$). Data obtained from 339 calvings between December 1, 1988, and March 1, 1990.

Table 7. Milk production, culling rate and postpartum disease for fourth and higher parity cows after various durations of placental retention ^a

Placental retention (hours)	n	Milk production (kg)	Culling		Disease		
		100 days post partum ($n=298$)	Culling rate (%)	Fertility ^b (%)	Displaced abomasum (%)	Milk fever (%)	Mastitis rate (first week) (%)
≤ 6	199	3478.5*	38.2*	23.7	0.5**	16.1	5.5
> 6	140	3347.4	36.4	35.3	4.3	16.4	8.6
≤ 8	237	3462.1	38.0*	24.4	0.8**	16.0	6.3
> 8	102	3335.7	36.3	37.8	4.9	16.7	7.8
≤ 12	244	3479.6**	37.0*	26.5	0.8**	17.0	6.4
> 12	95	3259.0	39.2	34.5	6.8	13.5	8.1
≤ 23	277	3469.6**	35.8	27.3	0.7**	17.0	6.1
> 23	62	3217.4	45.2	32.1	8.0	12.9	9.7
≤ 47	283	3462.6**	35.3	27.0	0.7**	17.0	6.0
> 47	56	3222.0	48.2	33.3	8.9	12.5	10.7
≤ 71	291	3454.6**	36.4	25.5*	1.0**	17.9	6.9
> 71	48	3236.2	43.8	42.9	8.3	6.3	6.3

^a Retention ≤ the time period is considered to be the non placental retention group and retention > time period the placental retention group.

^b Percentage of culled cows that was culled for fertility reasons.

* $P < 0.05$. ** $P < 0.01$.

for displaced abomasum increased with duration of retained placenta. The incidence rate for milk fever was not significantly different within the time groups and showed no trends. The incidence rate of mastitis was higher in the placental retention groups, than in the nonretention groups, but not significant. The incidence rates of cystic ovaries in the 6-hour duration group were 8.5 and 15.7 (non retained placenta and retained placenta), but these were not significantly different.

DISCUSSION

Since the incidence of retained placenta and of postpartum disease vary with age, the definition of retained placenta may also be age-dependent. Moving the definition of retained placenta from 6 to 71 hours decreases overall incidence rates over all age groups from 34.2 to 11.9. This shift emphasizes the importance of the manner in which retained placenta is defined.

We found a increasing risk of retained placenta with parity, which confirms earlier findings (4,7,9,10,13,17). Even when only single births were considered, the risk of retained placenta still increased with parity, as be posted in a previous study (9). However in a different report (8), researchers showed incidence rates were the same for all parities after correction for twins. After analysis, the effects of retained placenta were different for first calf heifers, for second and third parity cows and for fourth and higher parity cows.

Neither reproductive performance, nor culling rate of the first calf heifers was altered by retained placenta. Only cumulative 100- day milk production was significantly higher in the 8-, 12- and 23-hour retained placenta groups than in the nonretention groups. The incidence of mastitis occurring 1 week after calving was the lowest for heifers that expelled their placentas within 6 hours after calving. Incidence rates for lochiometra increased with duration of placental retention and showed significant differences within all duration groups. Heifers in the nonretention groups of 6, 8, 12, and 23 hours had less endometritis than heifers in the retention groups. In contrast to older cows, first calf heifers recover quickly from lochiometra, so lochiometra does not seem to be a risk factor for endometritis. Heifers not only expel their placentas earlier than cows, but even when expulsion is delayed it causes almost no effect on reproductive parameters. Based on the present investigation, we were not able to find an optimal definition of retained placenta for first calf heifers. There was no significant cut-off point, at which delayed expulsion of the placenta became detrimental for the performance of first calf heifers. Better condition of the endometrium, faster involution of the uterus, or a more effective immune system may be responsible for the minimal effects of retained placenta on the performance of first calf heifers.

Second and third parity cows showed significant differences in the occurrence of lochiometra and endometritis within all duration groups, but reproductive performance was not significantly influenced by duration of retained placenta. Cumulative 100-day milk production was most affected by retained placenta with a 12-hour duration. The difference in milk production between cows without and with retained placenta was 200 kg. Milk fever increased with increasing duration of placental retention, but may be a cause of retained placenta as well as an effect. Even when clinical signs of milk fever occurred after calving, there might have been subnormal blood calcium levels antepartum that had an effect on expulsion of the placenta. Mastitis in the first week of lactation had the highest incidence rate in cows with retained placenta for longer than 47 and 71 hours. There was no cut-off point at which we found a consistent detrimental effect on

the total performance of second and third parity cows. On the other hand, the best overall performance of second and third parity cows was found in animals that expelled their placentas within 6 hours.

Of all the variables analyzed for fourth and higher parity cows, reproductive performance was most altered by the duration of placental retention. Cumulative 100-day milk production was highest for the non retained placenta groups (6- and 12-hour duration). Postpartum disease occurred at the lowest rates for cows that had retained placenta for 6 or less hours. Cows that expelled their placentas within 6 hours after parturition had the lowest chance of being culled for fertility reasons. For fourth parity and higher cows overall performance was best when the cows expelled their placentas within 6 hours post partum.

Based on the overall performance of older cows, we may need to redefine retained placenta as failure to expel the placenta within 6 hours after parturition. It is not clear whether this redefining of retained placenta implies treatment after 6 hours, since treatment of retained placenta is still a controversial practice. Parenteral vs intrauterine treatment vs no treatment all need to be tested in clinical trials. In addition to establishing proper therapy, the optimal time of treatment must also be determined.

REFERENCES

1. Kay, R.M. Changes in milk production, fertility and calf mortality associated with retained placenta or the birth of twins. *Vet. Rec.* 102:477-479 (1978).
2. Martin, J.M., Wilcox, C.J., Moya, J. and Klebanow, E.W. Effects of fetal membranes on milk yield and reproductive performance. *J. Dairy Sci.* 69:1166-1168 (1986).
3. Lee, L.A., Ferguson, J.D. and Galligan, D.T. Effect of disease on days open assessed by survival analysis. *J. Dairy Sci.* 72:1020-1026 (1989).
4. Thompson, J.R., Pollak, E.J. and Pelissier, C.L. Interrelationships of parturition problems, production of subsequent lactation, reproduction, and age at first calving. *J. Dairy Sci.* 66:1119-1127 (1983).
5. Erb, H.N., Martin, S.W., Ison, N. and Swaminathan, S. Interrelationship between production and reproductive diseases in Holstein cows. Path analysis. *J. Dairy Sci.* 64:282-289 (1981).
6. Sandals, W.C.D., Curtis, R.A., Cote, J.F. and Martin, S.W. The effect of retained placenta and metritis complex on reproductive performance in dairy cattle - a case control study. *Can. Vet. J.* 20:131-135 (1979).
7. Halpern, N.E., Erb, H.N. and Smith, R.D. Duration of retained fetal membranes and subsequent fertility in dairy cows. *Theriogenology* 23:807-813 (1985).
8. Muller, L.D. and Owens, M.J. Factors associated with the incidence of retained placenta. *J. Dairy Sci.* 57:725-728 (1974).

9. Markusfeld, O. Periparturient traits in seven dairy herds. Incidence rates, association with parity, and interrelationships among traits. *J. Dairy Sci.* 70:158-166 (1987).
10. Lin, H.K., Oltenacu, P.A., Van Vleck, L.D., Erb, H.N. and Smith, R.D. Heritabilities of and genetic correlation among six health problems in Holstein cows. *J. Dairy Sci.* 72:180-186 (1989).
11. Erb, H.N., Martin, W.S., Ison, N. and Swaminathan, S. Interrelationships between production and reproductive diseases in Holstein cows. Conditional relationship between production and disease. *J. Dairy Sci.* 64:272-281 (1981).
12. Coleman, D.A., Thayne, W.V. and Dailey, R.A. Factors affecting reproductive performance of dairy cows. *J. Dairy Sci.* 68:1793-1803 (1985).
13. Erb, H.N. and Martin, S.W. Interrelationship between production and reproductive diseases in Holstein cows. Age and seasonal patterns. *J. Dairy Sci.* 63:1918-1924 (1980).
14. Erb, H.N. and Martin, S.W. Interrelationships between production and reproductive diseases in Holstein cows. Data. *J. Dairy Sci.* 63:1911-1917 (1980).
15. Grohn, Y.T., Erb, H.N., McCulloch C.E. and Saloniemi, H.S. Epidemiology of metabolic disorders in dairy cattle: association between host characteristics, disease, and production. *J. Dairy Sci.* 72:1876-1885 (1989).
16. Schukken, Y.H., Erb, H.N. and Smith, R.D. The relationship between mastitis and retained placenta in a commercial population of Holstein dairy cows. *Prev. Vet. Med.* 5:181-190 (1988).
17. Curtis, C.R., Erb, H.N., Sniffen, C.J., Smith, R.D. and Kronefeld, D.S. Path analysis of dry period nutrition, postpartum metabolic and reproductive disorders, and mastitis in Holstein cows. *J. Dairy Sci.* 68:2347-2360 (1985).