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Predicting the onset of parturition during late gestation in dairy cows using udder scoring and hormonal profiling

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ABSTRACT

Sixty-four cows were blood sampled and physical signs of impending parturition were scored daily from Day 272. Sampling and scoring ceased on Day 282 of gestation or when parturition occurred, whichever came about first. Mean udder development scores increased from 2.0 ± 0.76 (± SD) on Day –10 (ten days prior to parturition) to 3.2 ± 0.72 (± SD) on Day 0 (day of parturition) with 84% of cows having an udder score of 3 or 4 on the day prior to parturition (Day –1). Teat distension, vulva swelling and oedema were not useful as indicators of imminent parturition. Udder score was the most useful predictor, but the low frequency of scores less than 2 and greater than 3 on any one day resulted in unstable models. Plasma samples were assayed for progesterone, $PGF_{2\alpha}$ metabolites (PGFM), cortisol and oestradiol. Oestradiol concentration on Day 274 was a useful predictor of whether an individual cow would calve within eight days (P=0.02). Plasma oestradiol concentrations used to build models to predict whether a cow would calve within the next five days were accurate from Day 272 to 275 of gestation (P<0.05). Progesterone, PGFM and cortisol were unreliable indicators.

Keywords: dairy; parturition; udder scoring; oestradiol.

INTRODUCTION

Since the mid-1950s researchers have attempted to predict the onset of parturition for individual cows. Hormonal tests (Matsas *et al.*, 1992; Mee, 1988; Parker *et al.*, 1988), heart rates and respiration rates (Kimura *et al.*, 1991, 1992) have had varied success at predicting the onset of parturition. Vaginal mucus tests (Jarczyk, 1993; Winfield *et al.*, 1973) and vaginal and rectal temperatures (Ewbank, 1963; Iketaki *et al.*, 1982; Porterfield & Olson, 1957; Wrenn *et al.*, 1958) have been less consistently successful in predictions.

Most researchers have tried (with low success rates) to predict exactly when a cow will calve. The work presented here attempts to predict simply whether a cow will or will not calve within a given period, even when the parturition is less imminent. The primary aim of these studies was to determine whether a hormone or physical score measured on Day 274 of gestation could be used to identify individual cows which would or would not calve within the next eight days (on or before Day 282 of gestation). The importance of this is particularly relevant to future Controlled Calving program studies. Cows that are predicted to calve within eight days could be left untreated to result in spontaneous parturition prior to due calving date, while those predicted not to calve in the given period of eight days could be treated to induce the parturition process. The secondary aim was to determine whether measurements taken on any day of gestation in the range of Day 272 to 282 of gestation could be used to indicate whether a cow would calve within the next five days. This could be useful in herds that were using conventional AI programs (where cows are not at a common stage of gestation on any given day).

MATERIALS AND METHODS

Sixty-four cows were bled and udder scored daily in one commercial herd in Victoria. These cows had all conceived to a first insemination on 18/06/99 (Day 0). Sampling and scoring commenced on Day 272 of gestation and continued for a period of 11 days until Day 282.

The practice of feeding high-energy concentrates during the two- to three-week pre-partum period (lead feeding) provided the opportunity for scoring udder development and the collection of blood samples as pre-partum cows were taken to the dairy each day to be fed.

Blood samples were collected by coccygeal venipuncture into 10-ml glass tubes containing lithium heparin (143 I.U.; BD Vacutainer™) and placed on ice until the daily sampling was completed (maximum of 2 hours). They were then centrifuged at ~2000 rpm and stored at -20°C until they were assayed for progesterone, prostaglandin $F_{2\alpha}$ metabolites (PGFM), cortisol and oestradiol. The commercial kit SPECTRIA Progesterone RIA (Orion Diagnostica) was used to measure the concentration of progesterone in plasma. Intra-assay CVs ranged from 7.44% to 21.31% while inter-assay CVs ranged from 7.97% to 21.63%. PGFM assays were based on the direct radioimmunoassay (RIA) detailed by Burgess (1990). Intra-assay CVs ranged from 7.47% to 17.83% while inter-assay CVs ranged from 24.51% to 25.47%. Cortisol RIA's were carried out using the protocol published by Bocking (1986) with CVs very similar to those reported for PGFM. Oestradiol was analysed using a procedure that involved the commercial Estradiol MAIA® kit. Intra-assay CVs ranged from 9.97% to 14.06% while inter-assay CVs ranged from 18.39% to 23.71%.

Udder development was scored along with other external signs of imminent parturition (Table 1).

Statistical Analyses

SPSS 9.0 for Windows (1999, Chicago, Illinois) was used to evaluate the logistic regression models of plasma progesterone or oestradiol concentrations, and scored udder development (all measured on Day 274) with a

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TABLE 1: Classification of the visual external signs of imminent parturition in dairy cows close to term

	Oedema (subcutaneous abdominal vein or along escutcheon)	Udder Development	Teats (fore) distension	Teats (hind) distension	Vulval swelling
0	No visible oedema	Slack and very flaccid	Teats not distended	Teats not distended	No apparent enlargement of vulva
1	Small amount of oedema visible	Slight distension	Teats slightly distended	Teats slightly distended	Slight enlargement of vulva
2	Oedema very visible but not severe	Udder shows obvious signs of development with distension but not tight	Teats very distended	Teats very distended	Slightly enlarged vulva
3	Severe oedema	Udder very distended	Teats very distended and dripping colostrum	Teats very distended and dripping colostrum	Substantially enlarged vulva
4		Very extreme distention			

calving occurring within eight days (yes vs. no) as the outcome variable. Day 274 was used as this was the day of gestation that Controlled Calving programs were initiated in trials carried out by the author. Each potentially suitable parameter (progesterone, oestradiol and udder score) was evaluated individually with no other factors to determine the predictive power of each parameter on its own. Hosmer and Lemeshow goodness-of-fit statistics were used to determine the fit of each regression model to the data (Hosmer & Lemeshow, 1980). The regression equation developed for oestradiol concentration (Day 274) was then used to calculate the probability of each cow calving in the ensuing eight days given her plasma oestradiol concentration measured on Day 274 of gestation. Models were also built for measurements on each day of gestation (Day 272 to Day 282) to predict whether a cow would or would not calve within the next five days. This period was chosen as a value that would most likely be useful as an outcome without requiring samples or measurements to be carried out in a herd on a more frequent basis.

STATA (StatCorp, 2001) was used to determine the sensitivity, specificity, positive predictive value and the negative predictive value (Bland, 1995). STATA was also used to calculate the area under the receiver-operating-characteristic (ROC) curve (range zero to one) which provided a measure of the model's ability to discriminate between those subjects which experienced the outcome of interest versus those that did not (Hosmer & Lemeshow, 2000). An area of 0.5 showed no discrimination. A cut-off value of 0.75 was used for the probability of predicted calving (sensitivity and specificity intersected each other just under 0.76) within 8 days. The value was reduced to 0.5 for the 5 day predictions as this is a commonly used value when consistency is required over a range of models, as was the case here with a model developed for each day.

RESULTS

Mean concentrations are reported as ± SEM unless otherwise stated. Mean progesterone concentrations measured relative to day of parturition, decreased gradually from Day –10 (4.6 ± 0.3 ng/ml) to Day –3 (3.9 ± 0.2 ng/ml). These concentrations decreased to a mean level of 0.69 ± 0.2 ng/ml on the day of parturition (Day 0). Plasma oestradiol concentrations increased steadily from Day –9 (44.4 ± 4.0 pg/ml) to Day –1 (114.2 ± 7.9 pg/ml), then decreased to an average of 105 ± 10.7 pg/ml on the day of parturition. Mean PGFM concentrations remained below 1 nM from Day –10 to Day –2 before rising to 1.3 ± 0.2 nM on Day –1 and then to 2.5 ± 0.3 nM on Day 0. With PGFM levels remaining so low until the day before parturition, it is unlikely that this hormone would be of any use in predicting the day of parturition with blood samples taken prior to Day –1. Mean plasma cortisol concentrations ranged from 7.5 ± 1.0 ng/ml to 12.5 ± 1.6 ng/ml, but had no obvious pattern of change from Day –10 to Day 0. Due to the nature of the data, only the progesterone and oestradiol concentrations models will be reported here.

Mean udder development scores increased from 2.0 (Day –10) to 3.2 (Day 0) with 84% (21/25) of cows having an udder score of 3 or 4 on the day of parturition. Seventy-five percent (38/51) had a score of 3 or 4 on the day prior to parturition (Day –1). A large proportion of scored cows calved with foreteat distension scores of 2 or 3 (84%) and hindteat scores of 1 or 3 (72%). Mean vulva swelling scores were relatively stable with 62% of cows having a score 2 on the day of parturition. It was evident from plots of each of the parameters scored that udder score would be the most useful external sign of imminent parturition. It is the only sign that will be modeled and reported here.

Prediction for parturition within the next eight days from day 274 of gestation

The logistic regression with plasma progesterone concentrations (Day 274) as a covariate and calved within eight days (yes vs. no) as the outcome variable resulted in a model with a poor goodness of fit (P=0.045). Plasma progesterone concentration was a poor predictor of whether a cow would calve in the ensuing eight days (P=0.07).

A similar model developed for udder score was unstable with large 95% confidence intervals. There were no cows with a score of zero on Day 274 and few cows with scores of one and four (*n*=3 and 4 respectively) which resulted in a large SE and odds ratio for score 4. Scored udder development was a poor predictor of whether a cow would calve in the following eight days (P=0.69).

Plasma oestradiol concentration was a significant factor in the oestradiol model (P=0.02) which had a satisfactory goodness-of-fit (P=0.18). The odds ratio (1.0251) indicated that the odds of calving within the following 8 days increased by 2.51 percent for each one pg/ml increase in oestradiol concentration. Equation 1 was developed from the output of the logistic regression model.

Equation 1: Probability (P) of calving within eight days of Day 274 using plasma oestradiol concentration ([E2]) measured on Day 274 of gestation

$$P = \frac{e^{(const + B[E_2])}}{1 + e^{(const + B[E_2])}} = \frac{e^{(-0.1557+0.0248*[E_2])}}{1 + e^{(-0.1557+0.0248*[E_2])}}$$

Equation 1 was used to calculate the probability of individual cows calving within 8 days. Cows were then classified as having a probability greater than 0.75 (yes vs. no). The sensitivity of the predictions was 68.9% (31/45; 69% of cows calving were predicted to calve) and the specificity was 64.3% (9/14; 64% of cows that didn't calve were predicted to calve). The positive predictive value was 86.1% (31/36; probability of a test positive subject being a true positive) and the negative predictive value was 39.1% (9/23; probability of a test negative subject being a true negative). The area under the ROC curve was 0.73 (receiver-operating-characteristic curve).

Prediction for parturition within five days from measurements taken after a range of gestation lengths

Individual logistic regression models were generated with plasma progesterone and oestradiol concentrations and scored udder development as covariates and calving within five days (yes vs. no) as the outcome variable. These models were generated for each day of gestation from Day 272 to Day 282.

Scored udder development could not be used as a predictor of whether a cow would calve within the next five days, due to the nature of the data set. The low frequency of scores of 0, 1 and 4 on any one day of gestation resulted in unstable models.

Progesterone was significant in the models generated for Days 273, 274, 276 and 278 of gestation, however the parameter measurements of accuracy were not consistent.

The results of the oestradiol models suggested that oestradiol was a significant factor in the models generated for Day 272, 273, 274, 275 and 279 of gestation (P<0.05). The models generated for Days 272 to 275 (inclusive) had significant ROC values (P<0.05), which indicated that they were accurate predictors of whether a cow would calve within the next five days. After Day 275, the ability to accurately predict cows that would not calve (specificity and NPV) was compromised.

DISCUSSION

The findings presented here cannot be compared to the literature, as previous studies have tried to predict exactly when a cow would calve even when parturition was imminent. This work was more inclined to predict simply whether a cow would or would not calve within a given period when the parturition was less imminent.

The models involving udder score were too unstable to be reported. Combining any scores would have been an unsatisfactory solution, as the score system would be reduced to a two-score system and would be of little practical use. In reality, scored udder development collected on one farm in one year is unlikely to be a good predictor of when a cow will calve due to seasonal and herd variation in udder development.

Oestradiol (Day 274) was shown to be useful in predicting whether a cow would calve within eight days (by Day 282). In practical terms, using these predictions this may pose a problem in obtaining results quickly as a result of having to process samples. Blood progesterone kits are readily available (Matsas *et al.*, 1992; Parker *et al.*, 1988); however, these kits may be more useful in predicting whether a cow will calve within a given number of hours. This is influenced by the fact that progesterone is relatively stable in the 10 days leading up to calving, the concentrations decreasing only two to three days prior to parturition. The importance of oestradiol as a predictor would increase if this model were used retrospectively for analysis purposes. The ability to know when a cow would have calved if she had not been involved in a Controlled Calving Program may help to explain response time variation or why some cows had retained foetal membranes while others did not.

Plasma oestradiol concentrations measured on Day 274 of gestation were capable of predicting whether or not a cow would calve within the ensuing eight days. If this predictor was used to determine whether a cow should be included in a Controlled Calving Program, cows with probabilities less than 0.75 would be treated, which would result in 39% of tested cows being treated. Fourteen percent (1-PPV) of untreated cows would not calve within the following eight days. It would also mean that 61% (1-NPV) of the cows selected for treatment would have actually calved spontaneously prior to their due date. If the aim of the Controlled Calving Program was to reduce the spread of the calving period and reduce the variation of gestation length, then it would be more useful to have a higher negative predictive value than a lower positive predictive value.

Plasma oestradiol concentrations were the best predictor of whether a cow would calve within the next five days. The four-day period (Day 272 to Day 275) resulting in accurate models with high predictive power may be useful in the future in herds using conventional AI systems. Oestradiol was not a good predictor after Day 275 of gestation. This may have been a function of the reduced range of oestradiol levels measured as gestation length increased. Alternatively, it may have resulted from the reduced number of cows sampled on each day of gestation, due to the decreasing number of pre-partum cows in the population. It is possible that with more cows, accurate models could have been developed past Day 275 of gestation.

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