Effect of systematic parturition induction of long gestation Holstein dairy cows on calf survival, cow health, production, and reproduction on a commercial farm

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Abstract

The objective of this study was to evaluate the effect of parturition induction on dairy cattle with long gestation (past due-date) single pregnancies on calf survivability, cow health, production, and reproduction. There was an induction period during which all cows and heifers reaching 282 days of gestation were induced with dexamethasone (*n* = 614). Control cows calved the year after, had a gestation length > 282 d and were not induced (*n* = 508). As the induced and non-induced groups were not contemporaneous, data were standardized using the ratio between the herd baselines for each period. Multivariate analyses of the data showed that induced cows were 1.41 times more likely (*P* = 0.020) to become pregnant in the lactation following the studied calving than non-induced cows with long gestation. There was no difference in the risk of difficult calvings, stillbirths, culling due to reproductive reasons, average milk production, average days open or risk of abortion in the following lactation between induced and non-induced cows. There seemed to be a relationship between parturition induction and a lower risk of post-partum death, although this was not statistically significant (*P* = 0.162), because including induction as a factor in the model markedly improved the fit of the data. There was no information on incidence of retained placenta (RP) for the non-induced group. In conclusion, parturition induction resulted in more cows becoming pregnant and a seemingly lower risk of post-partum death without affecting calving difficulty, calf viability, or milk production.

Résumé

*L'objectif de la présente étude était d'évaluer l'effet de l'induction de la parturition chez des bovins laitiers avec une gestation unique prolongée (dépassée la date de parturition) sur la survie des veaux, la santé des vaches, la production et la reproduction. Il y avait une période d'induction durant laquelle toutes les vaches et les taures atteignant 282 jours de gestation ont été induites avec de la dexaméthasone (*n *= 614). Les vaches témoins ont mis bas l'année suivante, ont une durée de gestation de > 282 j et n'ont pas été induites (*n *= 508). Étant donné que les groupes de vaches induites et non-induites n'étaient pas contemporains, les données ont été standardisées en utilisant les ratios entre les niveaux de base des troupeaux pour chaque période. Les analyses multivariées des données ont montré que les vaches induites étaient 1,41 fois plus sujettes (*P *= 0,020) à devenir gestante au cours de la lactation suivant le vêlage étudié que les vaches non-induites avec une gestation prolongée. Il n'y avait aucune différence en ce qui regarde le risque de vêlages difficiles, de mortinatalités, la réforme pour des raisons de reproduction, la production laitière moyenne, la moyenne de jours ouverts ou le risque d'avortement durant la lactation suivante entre les vaches induites et non-induites. Il semblait y avoir une relation entre l'induction de la parturition et un risque plus faible de mortalité post-partum, malgré que la différence n'était pas statistiquement significative (*P *= 0,162), étant donné qu'en incluant l'induction comme facteur dans le modèle on améliorait de façon marquée l'ajustement des données. Il n'y avait aucune information sur la fréquence de rétention placentaire (RP) pour le groupe de vaches non-induites. En conclusion, l'induction de la parturition s'est soldée par plus de vaches devenant gestantes et l'apparence d'un risque plus faible de mortalité post-partum sans qu'on affecte les difficultés au vêlage, la viabilité des veaux ou la production laitière.*

(Traduit par Docteur Serge Messier)

Introduction

Although lactation can be hormonally induced (1), parturition is still considered a necessary event to initiate milk production in most cows. However, parturition can be a stressful event and many dairy cows are culled or die shortly after calving (2), mostly attributable to difficult deliveries, injuries during calving, or metabolic disease. Cows that experience stillbirths have been reported having higher risk for periparturient diseases such as retained placenta (RP), downer cow syndrome and metabolic diseases (3), low milk production (4), decreased fertility and a higher risk of dying or being culled (4,5).

Stillbirths and dystocia are associated with delivery of large calves (6,7), which in turn are associated with longer gestations

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(6–8). In fact, it has been established that the growth rate and weight gain of the bovine fetus is maximum during the last few weeks of the pregnancy (9). Therefore, shortening gestation length can be hypothesized to reduce the size of calves and therefore reduce the incidence of dystocia. Gestation length can be reduced by parturition induction (10–16) through administration of different salts of corticosteroids alone (10,11), or in combination with prostaglandins (12,13), estrogens (14), or relaxin (16).

Parturition induction is a management tool used in Australia and New Zealand to maximize pasture utilization (10,15,17). In this situation, premature parturition has been reportedly induced independent of gestation length, including cows that were pregnant for only 3 mo (resulting in a non-viable fetus) (10). Induced parturition has been associated with high incidence of RP (13,17) and lower milk production in the subsequent lactation (18,19). The incidence of RP in induced cows apparently varies in direct relationship with the amount of time between induction date and due date; cows induced 2 wk or more prior to due date had a higher incidence of RP (13,16,20), while cows induced within a week of due date had no difference in RP incidence compared with non-induced cows (12,20).

We hypothesize that a single dose of dexamethasone given to induce parturition in cows that are past the average due date (282 d) will 1) decrease incidence of difficult calvings and thus improve perinatal calf viability, 2) not increase reproductive and health problems in the cow, and 3) not decrease milk production in the subsequent lactation when compared with non-induced cows allowed extended gestation length beyond the recorded due date.

Materials and methods

Study herd

The study was conducted on a closed commercial 1500-milking cow dairy in northeast Spain. The voluntary period for the herd was 60 d. Heat detection was performed via pedometers (S.A.E. Afimilk, Kibbutz Afikim, Israel) and artificial insemination (AI) was the only breeding method practiced on the farm. Pregnancy was diagnosed via rectal palpation at 40 to 47 d after insemination. The combination of these methods ensured the accuracy of breeding dates. Cows included in the study were to have their 1st to 8th parturition. Mean gestation length was 279.3 ± 4.9 d (median = 280.0 d), calculated during the control period when there was no direct intervention that would affect this parameter.

On this farm, cows that show signs of imminent parturition (stage 1) were moved from a dry lot corral to individual calving pens to be closely monitored. Personnel were scheduled in the maternity area for 24 h/d. Each calving is assigned a "calving-ease" code: normal, for deliveries in which cows are not helped or are helped slightly by only one person; assistance needed, for deliveries where more than one person was needed to assist during delivery; posterior presentation; and dystocia, for deliveries needing repositioning of the calf or veterinary assistance (including cesarean sections). For the purpose of this study, deliveries coded as "assistance needed" or "dystocia" were classified as "difficult" calvings.

Parturition induction was started on this herd in October 1998 after 2 very difficult calvings in cows that had long gestation periods (297 and 299 d, respectively). Induction was stopped in May 2000 when a new herd manager was hired. Breeding management remained equal throughout the study length (October 1998 – May 2001), using the same pedometers to detect estrus, and the same voluntary waiting period and criteria for coding cows as "do not breed" (a combination of milk production, lactation number, conformation, and number of breedings). In May 2001 there was a major change in the administration and management of the herd introducing new criteria for breeding and culling decisions; therefore, data for this study includes only that collected until May 2001.

Trial design

This was a retrospective study performed by evaluating computerized and handwritten records. All cows and heifers that reached 282 d of gestation from October 1998 through April 2000, received a single IM administration of 0.1 mg/kg of sodium phosphate dexamethasone (Dexametasona CAG; Corporació Alimentària Guissona, Lérida, Spain). Parturition induction day was set systematically at 282 d of gestation because the custom herd management software identified this day as the nominal due date. Because all cows and heifers that reached 282 d during the induction period were induced, no control cows were available during this period. The control group for comparison, therefore, was formed by all cows and heifers that reached 282 d of gestation during the following year (May 2000 through May 2001) and were not induced. Due to the time difference between measurement of parameters in the induced group and the non-induced group, parameters for the non-induced group were standardized according to the baseline difference between periods (ratio of $CHF_{induced}$ to $CHF_{non\text{-}induced}$) as follows:

$$\text{Standardized value}_{non\text{-}induced} = \frac{CHF_{induced}}{CHF_{non\text{-}induced}} \times \textit{actual value}_{non\text{-}induced}$$

Baseline parameters were calculated for the rest of the cows of the herd that delivered singleton calves (gestation of ≤ 282 d) during each period. This portion of the herd was designated the complimentary herd fraction (CHF). Milk production data were standardized within parity. The standardized values for the control period were used as reference categories for the parameters of interest for the induced period. The CHF represented 77.1% of the singleton calvings during the induced period and 71.8% during the non-induced period.

Data collection

Production records were obtained and stored automatically via online milk meters (S.A.E. Afimilk) at each milking. Health, management, and production records for every animal in the herd were maintained electronically in custom software (Tauste Ganadera, S.A., Zaragoza, Spain). Data on RP were available only for the induction period from handwritten records of the maternity area. Data collected during the study included cow ID, lactation number, insemination date, calving date, "calving-ease" code, stillbirths (calves that were born dead or died within 24 h), incidence of RP (presence of fetal membranes for more than 24 h after calving), total milk production for the subsequent lactation, lactation length (days in milk or DIM), cows conceiving again (declared pregnant in the lactation following the studied calving), how long it took them to conceive again (days open), and which cows left the herd due to culling or death, and the reasons for leaving. Only deaths due to post-partum problems and culling due to reproductive reasons were used as a factor for the statistical analyses. All reasons related to reproductive impairment were lumped together to improve statistical power and clinical interpretation. The values for total milk production for the subsequent lactation and lactation length were used to calculate the average milk production per day present in the herd.

Data analyses

Sample size calculation to determine the difference between 10% of difficult calvings in control cows (non-induced) and an expected 8.5% in the induced group (assuming similar figures to the rest of the herd or CHF) at a level of significance of 5%, 80% power and continuity correction for sampling more than 10% of the herd yielded a requirement of 2849 cows in each group (induced and non-induced). Given that this would be impossible with a closed steady-state herd size of 1500 milking cows, statistical significance for this comparison will most likely not be achieved. Sample size calculation to determine a difference of 2 kg/cow/d in milk production at a level of significance of 5% and 80% power yielded 258 animals in each group (induced and non-induced). All animals that reached 282 d of gestation during the study were included in the analyses. Statistical analyses were performed using statistical software (Minitab 15; Minitab, State College, Pennsylvania, USA).

Continuous data are presented as mean ± standard deviation *(s)*, while categorical data are presented as percentages (absolute frequency/population size × 100). Baseline comparisons were performed between each study group (induced and non-induced) and their corresponding CHF. A standard Z-test was used to evaluate difference in proportions, and a Student's *t*-test for 2 samples with unequal variances was used for comparison of continuous variables between each study group and their corresponding CHF. Multivariate regression was used to evaluate if parturition induction was a risk factor for production and health differences in cows with a gestation length > 282 d (induced versus non-induced cows). Continuous outcome variables such as average milk production and average days open were evaluated using multiple stepwise regression (forward selection), using an alpha value of 15% to include a variable in the model. "Induction" (yes/no) was forced into every model to evaluate its significance as a risk factor for each studied outcome.

Dichotomous outcomes such as difficult calving (yes/no), stillbirth (yes/no), post-partum death (yes/no), culling due to reproductive reasons (yes/no), becoming pregnant in the lactation following the studied calving (yes/no), or abortion of this new pregnancy (yes/no) were studied by use of binary logistic regression using the logit link function (inverse of the cumulative logistic distribution function). "Induction" (yes/no) was forced into every model to evaluate its significance as a risk factor. The best fitting model was selected as that with the maximum log-likelihood and maximum *P*-value for the Hosmer-Lemeshow's goodness-of-fit test. Statistical significance for the test that all slopes of the predictive equation were zero was established at a level of 5%. Results with *P*-values > 5% but < 10% were deemed to be statistical tendencies (statistical significance was not achieved probably due to limited sample size).

Table I. Summary of results for a study of systematic parturition induction of long gestation Holstein cows. Induced and non-induced cows had a gestation length of at least 282 d. The complimentary herd fraction (CHF) for the corresponding period included only cows that delivered a single calf and had 282 days of gestation length or less. Data presented as mean ± s

	$CHF_{induced}$ ≤ **282 d**	*n*	Induced > **282 d**	*n*	*P*-value	$CHF_{non\text{-}induced}$ ≤ **282 d**	*n*	Non-induced > **282 d**	*n*	*P*-value
Gestation length (days)	277.1 ± 3.8	*2070*	284.3 ± 1.2	*614*	**< 0.001**	277.3 ± 3.8	*1294*	284.6 ± 2.3	*508*	**< 0.001**
Range	260–282		283–287			260–282		283–306		
Lactation number	2.4 ± 1.7	*2070*	3.0 ± 1.7	*614*	**< 0.001**	2.4 ± 1.7	*1294*	2.7 ± 1.6	*508*	**< 0.001**
Average milk production (kg)	28.0 ± 6.5	*2020*	27.8 ± 7.1	*596*	0.518	28.6 ± 6.3	*1153*	28.7 ± 7.0	*442*	0.783
Average days open	108.7 ± 61.5	*1307*	117.8 ± 70.6	*375*	**0.015**	100.9 ± 55.7	*847*	104.3 ± 61.0	*287*	0.383
Difficult calvings	8.7%	*2001*	9.4%	*593*	0.328	7.1%	*353*	10.3%	*126*	0.171
Stillbirths	9.2%	*2070*	11.6%	*614*	**0.046**	10.0%	*1294*	10.6%	*508*	0.385
Cows conceiving again	62.8%	*1837*	61.1%	*528*	0.255	65.5%	*1169*	56.5%	*446*	**< 0.001**
Abortions in following pregnancy	3.7%	*1307*	5.6%	*375*	0.069	4.5%	*847*	7.3%	*287*	**0.045**
Deaths due to post-partum problems	0.6%	*2070*	0.8%	*614*	0.399	0.7%	*1294*	2.2%	*508*	**0.007**
Culling due to reproductive reasons	7.8%	*2070*	8.1%	*614*	0.438	5.4%	*1294*	11.0%	*508*	**< 0.001**
Retained placenta	4.3%	*2070*	8.6%	*614*	**< 0.001**	No data	—	No data	—	

s — standard deviation; d — day.

Results

During the induction period there were 614 animals (cows and heifers) with singleton pregnancies that were induced, and 2070 completed records used for the herd average during this period. During the control period there were 508 animals non-induced (naturally long gestations), while 1294 animals contributed to the $CHF_{non\text{-}induced}$ average. Due to the retrospective nature of the study some cows were included in both groups; first year as induced and second year as non-induced (*n* = 127).

Inducing parturition at 282 d reduced not only the mean gestation length, but also the standard deviation of gestation length compared with the non-induced group ($P < 0.001$). The difference in gestation length does not appear biologically significant, although it masks the large range in non-induced cows (Table I) because most cows calved within a few days after day 282 of gestation. The difference in gestation length between induced and non-induced animals is more evident in Figure 1. Table I summarizes the results for the evaluated variables for the induced and non-induced groups, the CHF for each corresponding period, and the standardized values for the non-induced group. Tables II and III show results of multivariate analyses.

Despite the fact that gestation length for twins was on average almost 5 d shorter than for singleton calvings (274.1 ± 6.0 versus 278.8 ± 5.2, $P < 0.001$), there were 6 twin calvings in the induced group and 9 in the non-induced group during this study. Because twin calvings have been reported as a risk factor for post-partum disease and culling, only singleton calvings were included in the statistical analyses. Lactation number also was a factor that influenced gestation length. Cows in their 1st calving had a shorter gestation than cows with 2 or more calvings (277.8 ± 4.8 versus 279.4 ± 5.3, $P < 0.001$). A total of 30.1% of multiparous cows had long gestations (> 282 d), compared with only 12.0% of primiparous cows.

Calving difficulty and perinatal viability

Parturition induction did not influence the risk of difficult calvings [odds ratio (OR) = 1.07, $P = 0.844$] or the risk of stillbirths (OR = 0.74, $P = 0.578$) when compared with non-induced cows (Table II). Difficult calvings were associated with 47.0% stillbirths, which could explain why these 2 factors showed confounding throughout the statistical analyses. Therefore, only the factor with the most significant association was kept in the models. Calvings that resulted in a stillborn calf were 6.94 times more likely to be difficult than calvings resulting in a live birth ($P < 0.001$).

First lactation cows were 3.33 times more likely ($P < 0.001$) to have a difficult calving than non-induced cows, and 2.46 times more likely to deliver a stillborn calf ($P = 0.001$). Difficult calvings were associated with 47.0% stillbirths, compared with only 6.4% stillbirths in normal (unassisted) calvings ($P < 0.001$). This difference between difficult and normal calvings was consistent across lactation strata and most pronounced in primiparous cows (52.0% of stillbirths in difficult calvings and 10.0% in normal calvings, $P < 0.001$). Therefore, primiparous cows had higher proportion of stillbirths than 2nd and 3+ lactation cows (16.3% versus 5.3% and 6.8%, respectively, $P < 0.001$). Overall, dystocia was associated with 80.4% stillbirths, which was significantly higher ($P < 0.001$) than the

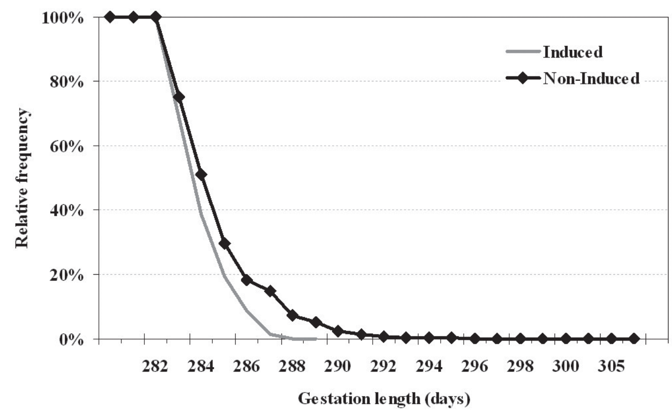

Figure 1. Survival curves of gestation length for a study of parturition induction in long gestation Holstein dairy cows (> 282 d of gestation). Comparison of gestation length in induced cows (*n* = 614) and non-induced cows (*n* = 508).

40.1% stillbirths in calvings needing assistance, 21.9% in posterior presentation calvings and 5.4% in normal calvings. Difficult calvings (those needing assistance, including dystocias) occurred mostly in primiparous cows (15.5%, $P < 0.001$).

Cow death and culling

Parturition induction was not significantly associated with a difference in post-partum deaths of cows when compared with non-induced cows (OR = 0.35, $P = 0.162$). Although there was no statistically significant association, including parturition induction as a risk factor in the model markedly increased the log-likelihood of the model (from −124.5 to −40.78) and the fit of the model that included only difficult calvings (from no convergence of the model to a Hosmer-Lemeshow's Goodness-of-Fit test with a *P*-value of 0.891 and a significant test of all slopes being zero — $P = 0.042$). According to the final model (Table II), cows were 5.80 times more likely to die if they had a difficult calving than if they had a normal calving ($P = 0.018$).

Parturition induction was not associated with culling due to reproductive reasons (OR = 1.11, $P = 0.663$). Risk factors for increased reproductive culling were not becoming pregnant in the lactation following the studied calving (OR = 12.50 inverse of OR = 0.08 for pregnant cows, $P < 0.001$) and being a multiparous cow (OR = 2.70 inverse of OR = 0.37 for primiparous cows, $P = 0.006$). There was also a tendency for increased culling due to reproductive reasons among cows that calved in the fall (September, October, and November) (OR = 1.73, $P = 0.054$).

Throughout the study, culling due to reproductive reasons was significantly lower in 1st lactation cows (5.3%) than in 2nd lactation cows (8.3%, $P = 0.002$) and 3rd + lactation cows (9.7%, $P < 0.001$). Reproductive culling was more likely associated with stillbirths (13.7%) than with live calf deliveries (7.1%, $P < 0.001$). Deaths due to post-partum problems were significantly higher among 3+ lactation cows (1.2%) compared with 0.5% in 2nd lactation cows ($P = 0.037$) but not compared with 1st lactation cows (0.7%, $P = 0.123$). Post-partum cow deaths were more likely associated with stillbirths (3.6%) than with live calf deliveries (0.5%, $P < 0.001$).

Table II. Summary of results of multivariate logistic regression analyses for a systematic parturition induction program in long gestation Holstein cows (> 282 days of gestation). Data expressed as OR, (95% CI) and *P*-value. *P*-values highlighted in gray are > 5% level of significance tested, but risk factors were kept because they improved the fit of the model

	Risk factors								
							Season		
Outcome variable	Induction	Primiparous cows	Difficult calving	Stillbirth	Conceiving again	Culling (reproductive)	2	3	4
Difficult calving	**1.07** (0.54, 2.14) *0.844*	**3.33** (1.92, 5.77) *< 0.001*		**6.95** (3.93, 12.30) *< 0.001*					
Stillbirth	**0.8** (0.44, 1.45) *0.457*	**2.46** (1.47, 4.11) *< 0.001*	**6.95** (3.93, 12.30) *< 0.001*						
Cows conceiving again	**1.41** (1.05, 1.88) *0.020*					**0.08** (0.05, 0.14) *< 0.001*			
Deaths due to post-partum problems	**0.35** (0.08, 1.52) *0.162*		**5.8** (1.35, 24.98) *0.018*						
Culling due to reproductive reasons	**1.11** (0.70, 1.75) *0.663*	**0.37** (0.18, 0.75) *0.006*			**0.08** (0.05, 0.14) *< 0.001*		**0.7** (0.33, 1.47) *0.342*	**1.33** (0.69, 2.56) *0.397*	**1.73** (0.99, 3.03) *0.054*

OR — odds ratio; 95% CI — 95% confidence interval

Seasons: (reference) 1 = Dec, Jan, and Feb
2 = Mar, Apr, and Jun
3 = Jul, Aug, and Sep
4 = Oct, Nov, and Dec

Table III. Summary of results of multivariate regression analyses for continuous outcomes for a systematic parturition induction program in long gestation Holstein cows (> 282 days of gestation)

	Average milk production (kg/cow/day)			Average days in milk (DIM)		
Risk factors	Coeficient	$S_{\bar{x}}$ Coef	*P*-value	Coeficient	$S_{\bar{x}}$ Coef	*P*-value
Constant	24.340	0.5795	< **0.001**	285.946	6.789	< **0.001**
Induction	−0.703	0.4007	**0.080**	15.046	5.63	**0.008**
Lactation length (DIM)	0.018	0.0017	< **0.001**	—	—	—
Primiparous cows	−3.393	0.4829	< **0.001**	25.493	6.803	< **0.001**
Death (post-partum disease)	−8.894	2.1750	< **0.001**	—	—	—
Culling (reproductive reasons)	−4.096	0.6351	< **0.001**	61.865	9.76	< **0.001**
Conceiving again	—	—	—	16.277	6.587	**0.014**

$S_{\bar{x}}$ standard error.

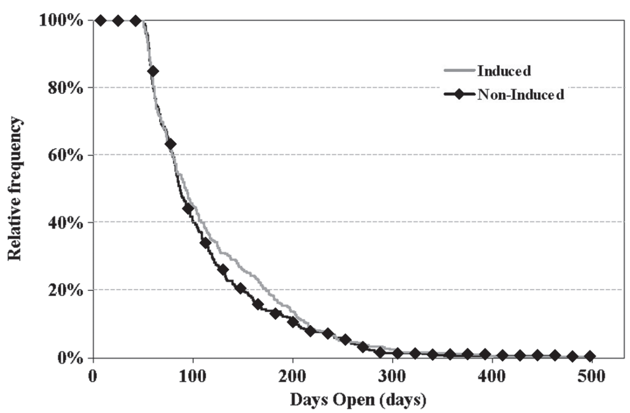

Figure 2. Survival curves of days to conception (days open) for cows that conceived again in a study of parturition induction in long gestation Holstein dairy cows (> 282 d of gestation). Comparison of days open in induced cows (*n* = 614) and non-induced cows (*n* = 508).

Reproduction and cow health

Induced cows were 1.41 times more likely to become pregnant again than non-induced cows ($P = 0.020$). The only other risk factor associated with risk of pregnancy was reproductive culls, which were 12.5 times less likely to be pregnant than cows that cows that were not culled or were culled due to other reasons (inverse of OR = 0.08 for pregnancy, $P < 0.001$). Risk of abortion and average days open (Figure 2) were not significantly associated to any of the studied variables.

Incidence of RP in induced cows was 8.6%, which could only be compared to the incidence of the $CHF_{induced}$ (4.3%, $P < 0.001$). Multivariate analysis of the risk of RP during the induction period (1998–2000) showed that induced cows were twice as likely to have RP than cows in the $CHF_{induced}$ group (singleton calvings from gestations < 282 days long). Additionally, primiparous cows were 1.61 times less likely to develop RP (OR = 0.62, $P = 0.020$). Also, there was a higher risk for RP in all seasons compared to winter (December, January, and February).

Retained placenta rates could not be evaluated in the control period ($CHF_{non\text{-}induced}$ and the non-induced group) or within lactation strata because data from the maternity handwritten records were not available. Of all RP, 59.42% happened in 3+ lactation cows ($P < 0.001$). Retained placenta was associated with longer days open compared to cows that did not have RP (132.2 ± 71.3 versus 110.1 ± 63.4, $P = 0.005$). However, there was no effect of RP on the proportion of cows conceiving again (52.8% — RP versus 61.8% — no RP, $P = 0.254$). There was also no effect of RP on proportion of cows culled due to reproductive reasons, cows that died due to post-partum problems, stillbirths or difficult calvings. There was a significant association between RP and a posterior presentation (10.1% versus 4.6% of cows with posterior presentation and no RP, $P = 0.003$).

Milk production

Average milk production was significantly higher during the control period than the induction period ($P = 0.007$) (Table I). After standardizing the non-induced group for the ratio between both CHF baselines (induced and non-induced), there was no difference in milk production between induced and non-induced cows ($P = 0.648$). This result was consistent across lactation strata. Average milk production did not change in the non-induced group after standardizing the distribution across lactation strata observed in the induced group. This standardization was performed to eliminate possible influence of the higher proportion of multiparous cows in the induced group compared to the non-induced group (multiparous cows have higher production than primiparous cows).

Multivariate analysis of average milk production per cow per day showed DIM as the only factor positively associated with milk production (higher DIM were associated with higher average milk production, $P < 0.001$) (Table III). Factors negatively associated with average milk production ($P < 0.001$) were primiparous cows (versus multiparous cows), cows culled due to reproductive reasons, and cows that died due to post-partum problems. Cows that were induced tended to produce on average 0.70 kg/cow/d less than non-induced cows ($P = 0.080$). Induced cows, however, produced milk for an additional 15 d compared with non-induced cows ($P = 0.008$). Other factors that increased average DIM for the lactation following the studied calving were primiparous cows and cows culled for reproductive reasons ($P < 0.001$) as well as cows that had conceived again ($P = 0.014$). The models explained only a small portion of the variability in milk production and DIM ($R^2 = 17.3\%$ and 5.8%, respectively).

The average lactation number was higher in the long gestation groups (induced and non-induced) compared with their respective CHF ($P < 0.001$) (Table I). This was mainly due to a difference in the proportion of primiparous cows: 19.9% in the induced group, 41.9% in the $CHF_{induced}$, 24.6% in the non-induced group and 39.8% in the $CHF_{non\text{-}induced}$.

Cows that delivered a live calf produced 2.1 kg/d more milk than cows that had a stillbirth (28.2 ± 8.2 versus 26.1 ± 6.3, $P < 0.001$). Cows with normal deliveries (not difficult) had a similar advantage in production over difficult calvings (28.0 ± 8.3 versus 26.5 ± 6.7, $P < 0.001$). These results were not confounded by many difficult calvings resulting in stillbirths. For example, cows with difficult calvings that produced a live calf produced 2.5 kg/day more milk than cows with difficult calvings that had stillbirths (27.6 ± 5.9 versus 25.2 ± 7.1, $P = 0.002$). Cows with normal calvings and a live calf also produced more milk than cows with normal calvings with stillbirths (28.1 ± 6.3 versus 26.7 ± 7.9, $P = 0.010$). Thus, independent of each other, stillbirths and difficult calvings were associated with lower milk production than live calves and normal calvings.

Discussion

The findings of this study were that systematic parturition induction of Holstein cows at 282 d of gestation did not affect the risk of difficult calvings or stillbirths, nor did it affect culling due to reproductive reasons during the following lactation. However, parturition induction increased the probability of pregnancy. Our result contrasts with that of a previous study (20) in which induced cows had lower pregnancy rates in the subsequent lactation. However that study induced cows 12 d earlier than the study herein. Other studies show no difference in the proportion of cows conceiving again (12,21). In spite of the higher probability in induced cows to conceive again in the next lactation compared with non-induced cows, induction was not a risk factor for increased days open. Previous studies (14,21) also show no difference in average days open between induced and non-induced cows.

Incidence of stillbirths was very similar in both groups and similar to the corresponding CHF; therefore, we conclude that inducing parturition in cows did not affect neonatal survival (positively or negatively). Our results are in agreement with other studies (15,19,22), although some studies have found a detrimental effect of parturition induction in neonatal viability when inducing parturition in cows with < 8 mo of gestation (10,11). It is possible that our results could have been influenced by arbitrary induction precisely at day 282 of gestation, which has been associated with the lowest perinatal mortality in a previous study (6). Inducing parturition with corticosteroids mimics the natural hormonal profile in the cow and the calf, allowing for physiological development such as the surfactant action in the calf's lungs (23). In this study, the chemical formulation used was a dexamethasone sodium phosphate, which has a much shorter duration of action and reaches higher serum concentrations (24) than long-acting formulations such as those used in other parturition induction studies: dexamethasone trimethyl acetate (12,15,21) and dexamethasone isonicotinate (21). No other induction studies using the sodium phosphate formulation of dexamethasone have been found. It is possible that the different chemical formulation of short-acting dexamethasone used in this study compared with other studies could account for some of differences between the results from this study and those others.

There was a similar incidence of assisted calvings in both groups. Personnel were available 24 h/d to observe calvings and intervene, if necessary, to improve neonatal survival. In dairies where calving observation is not constant, reducing the size of the calf through parturition induction may be effective in reducing neonatal mortality.

Comparison of induced cows with the $CHF_{induced}$ group (gestation length < 282 d) only showed differences in a larger average lactation number, a higher incidence of RP, and longer days open (Table I). The larger average lactation number in the induced group resulted because cows in this study were induced if they had not calved on their due date. It has been previously reported that heifers have shorter gestations than multiparous cows (6,8). The higher average lactation number, therefore, is explained by the higher proportion of multiparous cows reaching induction day because they have longer gestations. The result on incidence of RP is similar to that reported in other studies in which cows were induced within a week before their due date (12,20). However the incidence in our study was much smaller than the incidence of 38% to 100% reported in studies where cows were induced ≥ 2 wk before their due date (13,16,20). The increase in average days open in the induced group compared with the $CHF_{induced}$, although statistically significant, is not considered biologically significant because of its relatively small magnitude and the fact that it remains within the range of standards for production goals (between 95 and 125 d open) (25). All other studied parameters did not differ between the induced group and the $CHF_{induced}$ average. The fact that there was no difference in reproductive culling rates between induced cows and the $CHF_{induced}$ suggests that inducing parturition in cows close to their due date does not negatively affect reproduction in the subsequent lactation. This was confirmed by the finding that more induced cows conceived again compared with non-induced cows.

The 3 main reasons of involuntary culling on dairy farms have been reported as poor production, mastitis, and reproductive problems (26,27). In this study, cows allowed natural termination of gestation (non-induced) had significantly higher mortality due to post-partum problems, and more culling due to reproductive problems (involuntary culling), than cows with gestations < 282 d long ($CHF_{non\text{-}induced}$). It is reasonable to assume that culling due to reproductive reasons (repeat breeders, uterine scars, adhesions, and other uterine abnormalities) could be directly related to difficult calvings or calving accidents. Twice as many cows were culled in the non-induced group compared with the $CHF_{non\text{-}induced}$ baseline (Table I). However, the incidence of difficult calvings was not significantly different ($P = 0.123$) in non-induced cows and the $CHF_{non\text{-}induced}$. Although the association was not statistically significant due to small sample size ($n = 8$ dead cows), inclusion of induction as a risk factor for death due to post-partum problems was important in convergence of the model. Other studies have reported no difference in total culling or death of induced cows versus non-induced cows when assessing health effects of parturition induction on the dam (10,28,29). The discrepancy between our results and these studies may be due to our focus in reproductive culling instead of total culling.

The higher than average milk production during the control period (2000–2001) compared with the induction period (1998–2000) could be explained by better feed rations or better cow comfort. Another explanation could be the different proportions of 1st, 2nd, and later lactation cows in each group. Average milk production did not differ between each study group and the corresponding CHF average (gestation length < 282 d). This finding contrasts with that of other studies of parturition induction (18,19) that show a decrease in milk production in induced cows. Because the induced group had a higher percentage of multiparous cows compared to the non-induced group (favoring milk production towards the induced group), milk production in the non-induced group was adjusted for the proportion of 1st, 2nd, and 3+ lactation cows that were present in the induced group. The finding in our study that induced cows tended to produce 0.70 kg/cow/d less milk that non-induced cows could be confounded by the fact that induced cows had longer lactations than non-induced cows (extending the part of the lactation curve with the lowest daily milk production). Additionally, the increase in the proportion of induced cows that conceived again compared to non-induced cows could be considered a beneficial trade-off for the tendency to lower milk production. Our finding that higher DIM were associated with higher average milk production per cow per day could be explained by the fact that cows that make a longer lactation are kept because they produce enough milk to be profitable and those cows that are not profitable would be culled earlier.

Parturition induction has been reported to increase herd profitability (30,31). The economic impact of systematic parturition induction can be estimated by adding losses due to stillbirths, RP incidence, milk production, cow deaths, and culling because of reproductive reasons in induced and non-induced cows relative to their corresponding CHF averages. However, in this study it was not possible to evaluate the economic impact of parturition induction due to a lack of data on RP in the non-induced group and the impossibility of estimating actual losses in milk production in cows that died or were culled at different times during lactation. Economic evaluation of systematic parturition induction would depend largely on current values for cull cows and replacement heifers. However, these evaluations could not estimate losses in genetic value or those due to potential biosecurity risks when introducing new replacement animals. It would also be difficult to accurately estimate losses in milk production because of cows lost (death or involuntary culling) at different points in time during the lactation period. Primiparous cows usually have the best genetic potential and the largest residual cost of the herd because they have not had enough time to offset heifer-rearing costs. Therefore, losses due to death or involuntary culling in this group of animals generally result in the largest losses in the herd. In this study none of the 122 induced primiparous cows died due to postpartum problems versus a 3.0% death loss in the non-induced primiparous cows.

In conclusion, we found that inducing parturition in cows that were past the selected due date (282 d of gestation) was not detrimental to perinatal viability, was associated with a higher probability of the dam to become pregnant again, and could possibly be associated with a lower risk of death of the dam due to post-partum problems. Systematic parturition induction should be considered as an effective management tool in dairies.

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