Use of Prostaglandin $F_{2\alpha}$ as a Postpartum Reproductive Management Tool for Lactating Dairy Cows

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ABSTRACT

This study compared three programs for reproductive management of the postpartum period for reproductive performance and net economic benefit within three dairy herds (n = 1624 cows). Cows on one program received PGF_{α} injection at 25 to 32 d postpartum for reproductive therapy, and cows on a second program received additional $PGF_{2\alpha}$ at 39 to 46 d postpartum for synchronization of estrus. These programs were compared with a postpartum program of rectal palpation based on veterinary intervention. Survival analysis indicated that cows receiving $PGF_{2\alpha}$ for reproductive therapy and synchronization of estrus had an 11% higher rate of first AI and 10% higher rate of pregnancy than did cows receiving the rectal palpation. No differences existed between the cows receiving rectal palpation and those receiving the $PGF_{2\alpha}$. Because overall conception rates and conception rates at first AI did not differ among programs, the improved reproductive performance of cows receiving $PGF_{2\alpha}$ for both therapy and synchronization may be attributed to greater synchronization of estrus, which resulted in improved estrus detection. A partial budget indicated that the $PGF_{2\alpha}$ programs were less expensive than the rectal palpation program. When $PGF_{2\alpha}$ was used for postpartum reproductive therapy and synchronization of estrus, reproductive performance and net economic benefit were increased compared with those of the other programs.
(**Key words**: prostaglandin $F_{2\alpha}$, reproductive efficiency, reproductive programs)

Abbreviation key: **PG** = postpartum therapeutic $PGF_{2\alpha}$, **RP** = rectal palpation, **SI** = $PGF_{2\alpha}$ at a scheduled interval.

INTRODUCTION

Reproductive efficiency is often a limiting factor of dairy herd productivity and profitability (13, 21, 24, 25). Profits from a reproductive program are maximized when a majority of cows exhibit optimal reproductive performance (21, 25). Most economic models show an 11- to 13-mo calving interval as optimal for dairy cows (21, 24, 25). Rounsaville et al. (29) determined that detection of estrus and rate of conception were the major factors affecting reproductive performance. Because nearly half of the estrous periods in normally cycling cattle may be not detected (29), poor detection of estrus in herds using AI contribute to increased days open. Several studies (2, 29) have linked poor estrus detection to lengthened calving intervals. Therefore, economic losses associated with lengthened calving intervals often go undetected by dairy producers (25). Ranges of \$.25 to \$4.68/d open per cow beyond 85 d postpartum have been used to quantify costs of reproductive inefficiency (9).

Historically, postpartum reproductive programs have been based on routine rectal palpation (**RP**) of individual cows (11). Veterinary intervention may be based on routine RP examinations. Presently, the effectiveness of these traditional programs is in question. One alternative is the use of $PGF_{2\alpha}$ or its analogs

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as a tool for postpartum reproductive therapy (PG) and estrus detection or replacement of routine RP with programs based on the administration of $PGF_{2\alpha}$ at scheduled intervals (SI).

Regulation of estrus in cows has been achieved through the use of $PGF_{2\alpha}$ (8, 10, 19, 28, 30). Cows with a corpus luteum are expected to be in estrus within 120 h after treatment with $PGF_{2\alpha}$ (30). Although the licensed use of $PGF_{2\alpha}$ concerns synchronization of estrus, estrus induced by $PGF_{2\alpha}$ injected at 24 d postpartum resulted in a cleansing effect on the uterine environment and increased conception rates (7). Days open were fewer for cows treated with $PGF_{2\alpha}$ (30). Sequential injections of $PGF_{2\alpha}$ resulted in synchronization of estrus (8, 10, 19, 28, 30). Because RP is not sensitive for correctly identifying functional corpus lutea (18, 22, 26), improvements in detection of estrus and conception may result from SI to all open cows. Moreover, management of reproductive health would be based on the health of the whole herd rather than on the health of individual cows. However, a few studies (10, 19, 28) prospectively compare the effects of administration of $PGF_{2\alpha}$ to all open cows with those of a concurrent group involving routine RP. One uncontrolled field study (12) reported improved reproductive efficiency of open cows receiving SI. During the trial, days open decreased from 129 to 106 d (12). Controlled research (19, 30) suggested that an SI program might reduce days open and associated costs.

Thus, in this study, two reproductive management scenarios were developed, and each was compared with a program based on routine RP and intrauterine therapies. One protocol incorporated the following concepts: 1) RP is not sensitive for correctly identifying functional corpus lutea (18, 22, 26), 2) controlled studies indicate that the use of antibiotic or disinfectant uterine infusions may not be beneficial (23, 29), and 3) estrus induced by therapeutic use of PG may cleanse the uterine environment and increase fertility (7). Therefore, this protocol was designed to compare the therapeutic effects of $PG_{2\alpha}$ (Lutalyse™; Upjohn, Kalamazoo, MI) with the effects of postpartum therapies associated with routine RP. A second protocol incorporated the following concepts in addition to those of the other protocol: 1) SI may result in synchronization of estrus and improved reproductive efficiency (10, 19, 30), and 2) a higher percentage of estrus and conception, resulting in improved reproductive performance, was achieved when $PGF_{2\alpha}$ was administered at a 14-d interval rather than at an 11-d interval (10, 28). Thus, the second protocol was designed to compare the effects of PG combined with the use of $PGF_{2\alpha}$ to synchronize estrus with the effects of a program based on routine RP and intrauterine therapies.

The objective of this study was to compare, for herds using $PGF_{2\alpha}$ at the onset of the breeding period, three additional interventions: $PGF_{2\alpha}$ at 25 to 32 d postpartum, $PGF_{2\alpha}$ at both 25 to 32 d and at 39 to 46 d postpartum, and routine RP with no $PGF_{2\alpha}$ other than the use during the breeding period. The outcomes considered for the comparisons were days to first AI, days open, and net economic benefit. We hypothesized that the use of PG, replacing reproductive programs based on routine RP and intrauterine therapies, would result in a cost effective reduction in days open and improved reproductive efficiency. Subsequently, we postulated that this cost effective reduction in days open and improved reproductive efficiency would be further augmented through the combined use of PG for estrus detection, replacing routine RP with programs based on the administration of SI.

MATERIALS AND METHODS

Herd Selection

Before the inception of this study, specific criteria for herd participation were established so that the length of the study would not exceed 2 yr and participant herds would represent high management. Three cooperating clinicians from the Perry Veterinary Clinic (Perry, NY) were asked to identify herds that had >300 lactating Holstein cows that averaged >8636 kg of milk and <150 d open in the previous year. Table 1 contains baseline means for selected variables of the three Holstein herds. Participating herds were registered in the official Northeast DHI testing program (Ithaca, NY), and on-farm computerized records were maintained.

TABLE 1. Previous 12-mo means for reproductive performance of participating herds at initiation of study.

Term	Herd 1 (n = 345)		Herd 2 (n = 887)		Herd 3 (n = 439)	
	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
Days to first AI	82	22	87	29	81	25
Days open	149	114	117	71	131	67
Overall conception rate, %	34	2.6	59	1.7	50	2.4
Percentage of cows culled	35	2.5	20	1.3	25	2.1
305-d ME[1] Milk, kg	11,236	1889	10,026	1330	11,069	1040

[1]Mature equivalent.

Cow Assignment

At parturition, cows (n = 1624) were assigned randomly within herd and by parity group (primiparous or multiparous) to one of three reproductive management protocols. All cows in participating herds had equal opportunity for inclusion. However, cows defined by the producer as ineligible for breeding were excluded (herd 1, 8 out of 345; herd 2, 29 out of 887; and herd 3, 10 out of 439). Criteria for not rebreeding cows were herd-specific and generally based on production during a previous lactation, postpartum disorders, or breeding difficulties in a previous lactation. The study began March 10, 1992 and concluded October 4, 1993; cows were assigned from March 10, 1992 to July 1, 1993.

Before study initiation, a 10-d difference in days open was hypothesized to be essential to justify economically a particular protocol for reproductive management. Calculations of sample size indicated that a minimum of 415 cows per treatment was needed to detect a 10-d difference in days open, allowing compensation for losses (estimated as 10% of total enrollment). Sample size was determined using the parameters $\alpha = \beta = .05$ and SD = 40 d open, and a detectable difference of 10 d open (17).

Definition of Postpartum Reproductive Treatments

Before this study, in all three participating herds, a reproductive program based on routine RP and intrauterine therapy was followed, and $PGF_{2\alpha}$ was not used routinely. Experimental reproductive management protocols differed during the postpartum period by treatment group. To compare postpartum treatment effects, all cows received equivalent management programs during breeding and pregnancy. In addition, to reduce the potential for producer bias in management, detection of estrus, and veterinary treatment, no leg bands or other visual identification markers were used to identify cows by treatment. All data on treatment identification, collected monthly by the investigator, were recorded and stored on-farm using Dairy COMP 305® (Valley Agricultural Software, Tulare, CA).

RP Treatment. Cows receiving the RP treatment served as controls and followed a traditional reproductive program based on RP and associated therapies (e.g., intrauterine infusions and hormone therapy). All cows were palpated by a veterinarian at approximately 30 d (postpartum exam) and again at 50 d postpartum (prior to breeding exam). No $PGF_{2\alpha}$ was administered before the beginning of the breeding period. During the breeding period, $PGF_{2\alpha}$ was used at the discretion of the producer and veterinarian.

PG Treatment. Cows were administered a single injection of $PGF_{2\alpha}$ at 25 to 32 d postpartum in the PG treatment. To facilitate direct comparison of treatment effects between PG and RP, RP and associated therapies were prohibited in this treatment prior to the $PGF_{2\alpha}$ injection at 53 to 60 d postpartum.

SI Treatment. For the SI treatment, cows were injected with $PGF_{2\alpha}$ at 25 to 32 d and again 14 d after the initial injection (39 to 46 d postpartum). Cows observed to be in estrus following SI treatment were not bred. To facilitate direct comparison of treatment effects between SI and RP, routine RP and associated therapies were prohibited in SI.

To ensure an equivalent initial breeding period for each treatment and to differentiate the breeding period from the treatment effect, all cows were injected with $PGF_{2\alpha}$ at 53 to 60 d postpartum. Cows could not be inseminated until after they had received at least one injection of $PGF_{2\alpha}$. Therefore, a voluntary waiting period of 56 d was established for all herds. No estrus detection aids were used, and cows were artificially inseminated if they were observed to be in estrus or were retreated with $PGF_{2\alpha}$ 14 d after the initial injection if they were not bred. Estrus detection on participating farms consisted of daily visual observation at routine intervals. Any cow not observed to be in estrus by 70 d postpartum received veterinary intervention and returned to the biweekly schedule of $PGF_{2\alpha}$ injections at the producer's discretion.

All inseminated cows were examined for pregnancy by RP at 35 to 40 d post AI. Open cows were administered $PGF_{2\alpha}$ at 14-d intervals until they were observed to be in estrus and then were reinseminated.

Data Analyses

Because pregnancy was the event of interest for analyses of days open and first AI was the event of interest for analyses of days to first AI, cows that had not reached the breeding period (53 to 60 d postpartum) were excluded from analyses.

Analyses were performed using BMDP statistical software (4). The predictor variable was treatment. Cows were to be assigned to treatment randomly, within herd and by parity group (primiparous or multiparous). However, total cow enrollment during the period of study (RP = 533, PG = 498, and SI = 510) was inconsistent with expected differences across treatments. Therefore, parity group was considered to be a potentially confounding variable, and adjustments in the analyses were made for parity in addition to season of parturition and herd. Seasonal categories were March to May, June to August, September to November, and December to February.

Survival Analysis: Days Open

The effects of treatment on days open was quantified using survival analysis. Survival analysis is a regression technique for data analysis in which the outcome variable is timed to an event (1, 3, 15, 16). The outcome variable for this analysis was a postpartum interval, days open, defined as the time between parturition and conception. Use of survival analysis for analysis of reproductive data is advantageous because the probability of an event (e.g., pregnancy) is calculated for consecutive days postpartum, enabling simultaneous analysis of censored and uncensored data (1, 3, 15). Censored data are contributed by those cows (open cows) not experiencing the event of interest (pregnancy). In this analysis, data for cows that were culled during days open after the end of the voluntary waiting period and data for cows that were still not pregnant by the end of the study were considered to be censored. Data for an open cow with DIM greater than or equal to the voluntary waiting period was also considered to be censored. For censored records of cows that were inseminated, days open was calculated as days from parturition to last date of AI (unconfirmed pregnancy) or last date of data collection (confirmed open). For censored data for cows that were not inseminated, days open were calculated as days from parturition to the date of culling or the last date of data collection.

Data were analyzed using the following Cox proportional hazards regression model:

$$h_{ij}(t) = h_{0j}(t)\exp\{\text{treatment} + \text{lactation} + \text{season}\}.$$

This analysis was stratified by herd because pregnancy rates (number of pregnancies per time) varied between herds. The probability of cow i in herd j becoming pregnant at t days after parturition was described by $h_{ij}(t)$, the hazard function. When all covariants were equal to 0, the unknown baseline probability of pregnancy was characterized by $h_{0j}(t)$, the baseline hazard function. For each independent variable in the model, a hazard ratio (analogous to a relative risk) was estimated. Hazard ratios, which estimate the rate of pregnancy with a base, were calculated raising exponentially 2.718 to the beta power. The pregnancy rate used in survival analysis is a true rate because survival analysis estimates the number of pregnancies per unit of time (1, 3, 19, 20). The difference between treatments that were described by the hazard ratio was assessed by independently plotting Kaplan Meier estimators for the RP and SI treatments to obtain median days open. All tests of statistical significance ($P < .05$; two-sided) in the regression analysis were performed using the likelihood ratio test. A partial likelihood method was used to estimate the parameters of the model. In addition to main effects, all second-order interactions were estimated and were nonsignificant.

Survival Analysis: Days to First AI

The effects of treatment on days to first AI were quantified using survival analysis. The outcome variable for this analysis was a postpartum interval, days to first AI, defined as the time between parturition and first AI. In this analysis, data for cows that were culled after the end of the voluntary waiting period but before they were inseminated and cows that were still not inseminated by the end of the study were considered to be censored. Essentially, data for noninseminated cows with DIM greater than or equal to the voluntary waiting period were considered to be censored for this analysis. For data on censored cows, days to first AI were calculated as days from parturition to the date of culling or the last date of data collection. Data analysis was performed exactly as for days open, except that the outcome variable was first AI rather than pregnancy, and the maximum censoring time was the maximum observed days to first AI, 163 d.

Additional Analyses

Chi-squares with a Type 1 error of .05 were used for pooled data across herds; descriptive statistics were compared for first AI conception rates, culling rates, and the proportion of pregnancies among treatments. The cumulative incidence of postpartum disorders (including displaced abomasum, ketosis, metritis, milk fever, ovarian cysts, pyometra, retained placenta) was summarized and compared by inspection across treatments. Finally, a partial budget was used to evaluate the net benefits of the three treatments. Costs reflected fees charged by the Perry Veterinary Clinic from March 1992 to October 1993. Costs included in the analysis were rectal palpation fees ($2.25 per palpation), drug costs of $PGF_{2\alpha}$ ($2.25 per dose), and postpartum therapy ($10.88 per treated cow). The sensitivity analyses were done only for the cost of $PGF_{2\alpha}$ because $PGF_{2\alpha}$ was the focus of the study. The therapeutic costs were calculated by the actual incidence of health events and associated costs in the three herds.

RESULTS

Days Open

The analysis was based on 472 RP cows on the treatment, 443 on PG treatment, and 461 on SI treatment. Of the data included in the analysis, records were censored for 93, 97, and 79 cows on the RP, PG, and SI treatments, respectively. The SI treatment was the only significant variable in the final Cox proportional hazards regression model (Table 2). No difference existed in hazard ratios between PG and RP treatments (Table 3). The hazard ratio for SI treatment was 1.10 when all other covariables were controlled. Therefore, after parity group (1 or >1) and season of parturition were controlled, the SI treatment resulted in a hazard ratio of 1.10, which indicates that cows on the SI treatment had a 10% higher pregnancy rate than did cows on the RP treatment, which may be a result of greater synchronization of estrus postpartum.

Sixty-one, 55, and 49 cows receiving RP, PG, and SI treatments, respectively, were culled prior to breeding, and their records were not included in the analysis. The exclusion of records for cows that were culled before breeding prompts the question of confounding. Confounding would be a concern if culling rate were related to treatment and outcome. However, the data indicate that postpartum treatment likely did not affect culling rate (RP = 11%, PG = 11%, and SI = 10%). Because treatment and culling rate are probably not related, no potential exists for confounding when these data are excluded from analyses. Finally, records for all cows with DIM ≥56 d postpartum were included in the analysis: 472 RP, 443 PG, and 461 SI records satisfied this criterion for inclusion.

Kaplan Meier estimators were independently plotted for SI and RP treatments to illustrate the cumulative pregnancy rates of

TABLE 2. Cox proportional hazard multiple regression model for days open.[1]

Term	Coefficient[2]	SE	Wald[3]	LRCS[4]
Lactation[5]	−.01	.07	.86	. . .
Season[6]				
1	−.01	.12	.98	. . .
2	.14	.09	.14	. . .
3	.06	.09	.53	. . .
Treatment[7]				
1	−.08	.06	.18	.19
2	.09	.04	.03	.03

[1]Analysis was stratified by herd.

[2]The coefficients for the categorical variables represent the $\log_e$ of the ratio of hazard functions for different levels compared with the base level.

[3]Wald statistic test is based upon the asymptotic normality of the maximum likelihood estimates.

[4]Likelihood ratio chi-square statistic for treatment.

[5]0 = 1, 1 = >1.

[6]0 = December to February, 1 = March to May, 2 = June to August, and 3 = September to November.

[7]0 = Rectal palpation (n = 472): 1 = postpartum therapeutic prostaglandin (n = 443), and 2 = scheduled interval prostaglandin (n = 461).

cows on these treatments (Figure 1). This technique determined median days open for SI treatment at 107 d and for RP treatment at 113 d (Figure 1). Because hazard ratios of PG and RP treatments were not statistically different ($P > .05$), the cumulative pregnancy rate of cows on the PG treatment was not plotted.

The impact of any violations of independence between censoring and the occurrence of the event was assessed by substituting extreme values for censored observations. Once the model was estimated, then the data were altered to the time of censoring had the event occurred (i.e., confirmed pregnant). Another time, all censoring times were set to be equal to the maximum time value (339 d open) observed in the data, and the model was again estimated. The parameter estimates from the standard analysis and the two extreme analyses were similar, which satisfied the assumption of independence (1, 3, 14, 15).

The assumption of the Cox proportional hazards model that the effects of treatment were independent of time (the proportional hazards assumption) also was tested. Each independent variable was stratified, and logarithmic transformations of the cumulative hazard function for each stratum were plotted. The survival curves were parallel (by inspection) and thus satisfied the assumption of proportional hazards (1, 3, 14, 15).

Days to First AI

The analysis was based on 472 cows on RP treatment, 443 on PG, and 461 on SI. Of the cows included in the analysis, 41 on RP, 41 on PG, and 29 on SI were censored. The SI treatment was the only significant variable in

TABLE 3. Hazard ratios and 95% confidence intervals (CI) for days open model.[1]

Term	Hazard ratio[2]	95% CI
Lactation[3]	.99	.5 to 1.1
Season[4]		
1	.99	.6 to 1.5
2	1.16	.9 to 1.7
3	1.06	.6 to 1.4
Treatment[5]		
1	.93	.7 to 1.2
2	1.10	1.03 to 1.6

[1]Analysis was stratified by herd.

[2]Hazard ratios were calculated by raising e (2.718) to the β power. The hazard ratio estimates the rate of pregnancy for different levels compared with a base level.

[3]0 = 1, 1 = >1.

[4]0 = December to February, 1 = March to May, 2 = June to August, and 3 = September to November.

[5]0 = Rectal palpation (n = 472), 1 = postpartum therapeutic prostaglandin (n = 443), and 2 = scheduled interval prostaglandin (n = 461).

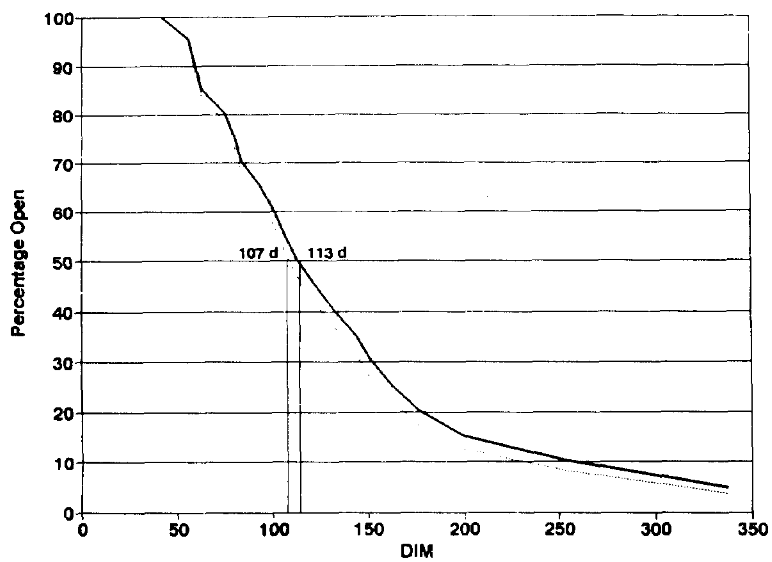

Figure 1. First AI rates (AI per time) in three participating herds for cows on $PGF_{2\alpha}$ at a scheduled interval (---; n = 461) and rectal palpation (—; n = 472) treatments.

the final Cox proportional hazards regression model (Table 4). There was no difference in hazard ratios between PG and RP treatments (Table 5). The hazard ratio for SI treatment was 1.11 when other covariables were controlled. Therefore, after parity group (1 or >1) and season of parturition were controlled, the SI treatment resulted in a hazard ratio of 1.11, indicating that cows under SI treatment had a 11% higher first AI rate than cows under RP treatment. The cows on the SI treatment received three $PGF_{2\alpha}$ injections prior to breed-

TABLE 4. Cox proportional hazard multiple regression model for days to first AI.[1]

Term	Coefficient[2]	SE	Wald[3]	LRCS[4]
Lactation[5]	.01	.06	.98	. . .
Season[6]				
1	–.10	.09	.28	. . .
2	.13	.07	.09	. . .
3	.11	.07	.14	. . .
Treatment[7]				
1	–.02	.07	.79	.81
2	.12	.06	.04	.04

[1]Analysis was stratified by herd.

[2]The coefficients for the categorical variables represent the $\log_e$ of the ratio of hazard functions for different levels compared with the base level.

[3]Wald statistic test is based upon the asymptotic normality of the maximum likelihood estimates.

[4]Likelihood ratio chi-square statistic for treatment.

[5]0 = 1; 1 = >1.

[6]0 = December to February, 1 = March to May, 2 = June to August, and 3 = September to November.

[7]0 = Rectal palpation (n = 472), 1 = postpartum therapeutic prostaglandin (n = 443), and 2 = scheduled interval prostaglandin (n = 461).

ing compared with one $PGF_{2\alpha}$ injection for the cows on the RP treatment. The greater number of $PGF_{2\alpha}$ injections for the SI group resulted in greater synchronization of estrus and earlier DIM to first AI.

Plots of the Kaplan Meier estimators showed median days to first AI for SI treatment to be 63 d compared with 71 d for the RP treatment (Figure 2). Because hazard ratios of PG and RP treatments were not statistically different ($P > .05$), the cumulative first AI rate of PG treatment was not plotted.

TABLE 5. Hazard ratios and 95% confidence intervals (CI) for days to first AI model.[1]

Term	Hazard ratio[2]	95% CI
Lactation[3]	1.01	.7 to 1.2
Season[4]		
1	.91	.6 to 1.5
2	1.14	.7 to 1.4
3	1.11	.5 to 1.2
Treatment[5]		
1	.98	.7 to 1.3
2	1.11	1.07 to 1.5

[1]Analysis was stratified by herd.

[2]Hazard ratios were calculated by raising e (2.718) to the β power. The hazard ratio estimates the rate of pregnancy for different levels compared with a base level.

[3]0 = 1; 1 = >1.

[4]0 = December to February, 1 = March to May, 2 = June to August, and 3 = September to November.

[5]0 = Rectal palpation (n = 472); 1 = postpartum therapeutic prostaglandin (n = 443), and 2 = scheduled interval prostaglandin (n = 461).

Descriptive Statistics

Table 6 contains descriptive statistics for reproductive performance that were not important ($P > .10$) among treatments. The effect estimates from the survival analysis differed from the univariable descriptive statistics because they were adjusted for the other variables in the model. By inspection, the cumulative incidence of displaced abomasum, ketosis, milk fever, and retained placenta was not different among treatments (Table 7) and was consistent with results of previous studies (5, 6). By inspection, the cumulative incidence of metritis, ovarian cysts, and pyometra differed among treatments (Table 7), most likely a result of the study protocol, because each of these disorders is diagnosed via rectal palpation, which was prohibited in the PG and SI treatments. In addition, the cumulative inci-

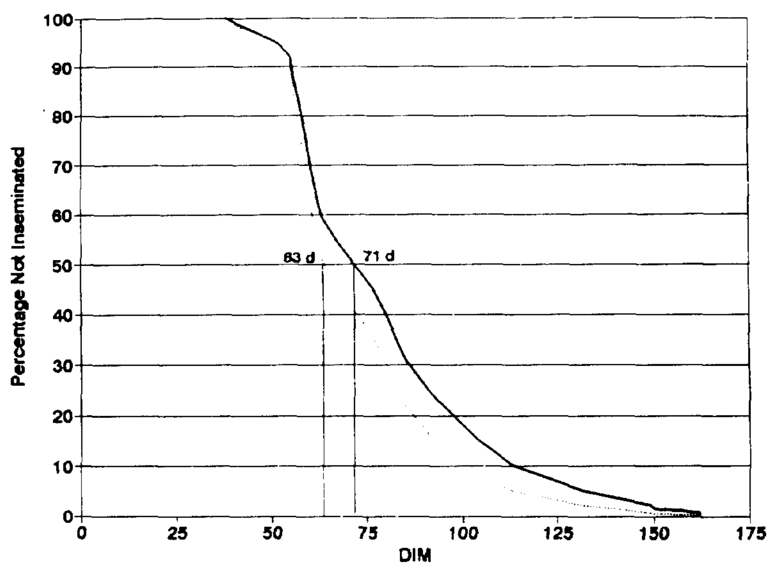

Figure 2. Pregnancy rates (pregnancies per time) in three participating herds for cows receiving $PGF_{2\alpha}$ at a scheduled interval (---; n = 461) and rectal palpation (—; n = 472).

TABLE 6. Univariate descriptive statistics for reproductive performance by treatment.

Term	RP[1] (n = 472)		PG[2] (n = 443)		SI[3] (n = 461)	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
First AI conception rate,[4] %	43	2.3	45	2.4	47	2.3
Overall conception rate,[5] %	51	2.3	53	2.4	53	2.3
Inseminated cows pregnant, %	88	1.5	86	1.6	88	1.5
Cows culled,[6] %	21	1.9	21	2.0	20	1.8
Days open						
All cows	113	38	114	39	107	29
Pregnant cows	111	43	111	41	104	35
AI per conception[7]	2.0	1.0	1.9	1.0	1.9	.98

[1]Rectal palpation treatment.

[2]Postpartum therapeutic $PGF_{2\alpha}$ treatment.

[3]Scheduled interval $PGF_{2\alpha}$ treatment.

[4][(Total conceptions resulting from first AI)/(total cows with a first service)] × 100.

[5][(AI per conception on all services)] × 100.

[6][(Total cows culled)/(total cows enrolled)] × 100.

[7]Inseminations per conception on all inseminations.

dence of metritis, ovarian cysts, and pyometra in the RP treatment was consistent with those in previous studies (5, 6). Uterine therapies that were administered were not recorded.

Partial Budget and Sensitivity Analysis

Costs for PG treatment were $4.46 less per cow than the costs of RP treatment. The SI treatment cost $3.61 less per cow than RP treatment but saved 6 median d open per cow compared with those on RP treatment (Table 8). When the value of a saved day open was assumed to be $2.00/d per cow (9), net costs for the PG treatment did not change, but, for the SI treatment, were reduced from $3.61 to $15.61 less per cow than the costs of RP treatment. Break-even analyses (Table 8) showed that the break-even costs of $PGF_{2\alpha}$ of the SI treatment, with and without postpartum therapeutic costs, were $5.02 and $3.53, respectively. When the price of a dose of

TABLE 7. Cumulative incidence of postpartum disorders by treatment.

Postpartum disorders[4]	RP[1] (n = 472)		PG[2] (n = 443)		SI[3] (n = 461)	
	(%)	(no.)	(%)	(no.)	(%)	(no.)
Displaced abomasum	3.0	14	2.0	9	4.0	18
Ketosis	1.3	6	1.4	6	1.1	5
Metritis[5]	8.9	42	0	0	0	0
Milk fever	2.3	11	2.0	9	2.4	11
Ovarian cyst[5]	11.0	51	3.2	14	3.3	15
Pyometra[5]	.8	4	0	0	0	0
Retained placenta	7.6	36	6.8	30	7.4	34

[1]Rectal palpation treatment.

[2]Postpartum therapeutic $PGF_{2\alpha}$ treatment.

[3]Scheduled interval $PGF_{2\alpha}$ treatment.

[4]Clinical cases diagnosed during the postpartum period.

[5]Diagnosis via rectal palpation occurred 25 to 100 d postpartum.

$PGF_{2\alpha}$ varied from $2.25 to $3.00 and from $3.00 to $4.00, results of the partial budget did not change (Table 8). Combined costs of $3.00 per dose of $PGF_{2\alpha}$ and a less expensive palpation cost of $.90 resulted in PG and SI costs of $1.01 and $11.87 less per cow, respectively, than costs of RP treatment. Thus, the interpretation of the cost-benefit relationship of using $PGF_{2\alpha}$ as in this study, is dependent on value of days not pregnant, $PGF_{2\alpha}$ costs, and palpation and associated therapy costs.

DISCUSSION

Postpartum Therapeutic Tool

A PG program consisting of a therapeutic injection of $PGF_{2\alpha}$ at 25 to 32 d postpartum (RP) was compared with an RP program based on routine RP and intrauterine therapies. A reproductive program consisting of a therapeutic injection of $PGF_{2\alpha}$ at 25 to 32 d postpartum (RP prohibited) may result in equivalent reproductive performance compared with a program based on routine RP and intrauterine therapies. Pregnancy rate, first AI rate, first AI conception rate, overall conception rate, percentage of AI cows that became pregnant, and culling rates were not different between PG and RP treatments. Pregnancy rate is a function of conception rate and efficiency of estrus detection (2, 8, 25, 29). Therefore, reproductive performance was not different among treatments, probably because reproductive performance and efficiency of estrus detection were similar. Although no differences in reproductive performance occurred among treatments for PG and RP, partial budgeting indicated that PG treatment cost was $4.46 less per cow than the cost of RP treatment.

Results of this comparison are supported by previous research (18, 22, 23, 26, 27) demonstrating that therapies associated with routine RP do not improve reproductive efficiency.

TABLE 8. Partial budget[1] and sensitivity analysis[2] for postpartum therapeutic $PGF_{2\alpha}$ (PG) and $PGF_{2\alpha}$ treatments at scheduled intervals (SI) compared with rectal palpation (RP) treatment.

Term	RP	PG	SI
Partial budget			
Number of cows	472	443	461
Doses of $PGF_{2\alpha}$[3,4]	1289	1630	1890
Cost of $PGF_{2\alpha}$[3,4] at $2.25 per dose, $	2900	3668	4253
Rectal palpations,[5] no.	944	0	0
Cost of rectal palpation at $2.25 per palpation, $	2124	. . .	. . .
Cost of postpartum therapy[6] at $10.88 per treated cow, $	1055	435	163
Total costs, $	6079	4103	4416
Cost difference between treatments, $	. . .	−1976	−1663
Cost difference per cow, $	. . .	−4.46	−3.61
Median days open saved per cow, d	. . .	0	−6
Value of saved days open at $2.00/d per cow, $	. . .	. . .	−12.00
Net cost per cow (compared with RP treatment), $	. . .	−4.46	−15.61
Sensitivity analysis			
$PGF_{2\alpha}$[3,4] $5.02 per dose and days open saved = 0	. . .	−2.33	0
$PGF_{2\alpha}$[3,4] $3.53 per dose, therapy costs = $0, and days open saved = 0	. . .	−2.08	0
$PGF_{2\alpha}$[3,4] $3.00 per dose	. . .	−3.88	−14.70
$PGF_{2\alpha}$[3,4] $4.00 per dose	. . .	−3.12	−13.33
$PGF_{2\alpha}$[3,4] $3.00 per dose and rectal palpation at $.90	. . .	−1.01	−11.87

[1]Using baseline costs.

[2]Net cost per cow compared with costs of RP treatment with the indicated changes.

[3]Includes all postpartum and breeding period injections.

[4]Lutalyse™ (Upjohn, Kalamazoo, MI).

[5]Includes all prebreeding palpations (excludes pregnancy palpations).

[6]Costs (drugs and additional palpations) incurred between 25 to 100 d postpartum.

Therefore, compared with a traditional reproductive program on RP, the use of PG without RP could result in equivalent reproductive performance at lower costs. Because the purpose of our study was to compare the use of PG to traditional RP program in current use, it was outside the scope of our study to test RP alone. Thus, the value of routine RP of all postpartum cows for subsequent reproductive performance was not determined.

Tool for Detection of Estrus

The efficacy of administering PG combined with use of $PGF_{2\alpha}$ to synchronize estrus ($PGF_{2\alpha}$ injected at scheduled 14-d intervals after 25 to 32 d postpartum, routine RP prohibited) was compared with a traditional RP program with veterinary intervention (SI vs. RP). Administration of a therapeutic injection of $PGF_{2\alpha}$ combined with use of $PGF_{2\alpha}$ to synchronize estrus is cost-effective and can enhance reproductive performance compared with a traditional RP program. Cows in the SI treatment had higher pregnancy rates and higher rates of first AI, which resulted in fewer days to first AI and fewer days open than for cows receiving a traditional program that relied on routine RP and intrauterine therapies. Improved reproductive performance may be attributed to the greater synchronization of estrus during the postpartum period. Barr (2) established that a decrease of 1 d to first AI corresponds to a decrease of .8 d open. Comparison of SI and RP treatments yielded results (a decrease of 8 median d to first AI, which resulted in a savings of 6 d open in the SI treatment) consistent with those of Barr (2). Rates of first AI conception, overall conception, percentage of AI cows that became pregnant, and culling were not different between cows on SI and RP treatments, which indicates SI and RP cow reproductive performance was similar.

Although the work of Slenning and Farver (31) suggested that administration of $PGF_{2\alpha}$ during breeding lowered the efficiency of estrus detection, SI yielded greater synchronization of estrus prior to breeding, which increased estrous activity during the breeding period (8, 10, 12, 19, 28). Part of the improved reproductive performance of SI treatment was due to the decrease in days to first AI compared with that of cows on the RP treatment. Because conception rates at first AI and overall conception rates were not different among treatments, the fewer days to first AI and to conception and subsequent higher pregnancy rates of SI treatment can be attributed to greater synchronization of estrus, which resulted in earlier AI in SI treatment. In addition, because reproductive performance was not different between PG and RP treatments, the improved reproductive performance of SI treatment compared with RP treatment can be attributed directly to improved synchronization of estrus rather than to postpartum therapeutic effects of $PGF_{2\alpha}$.

The partial budget analysis considered rectal palpation fees, postpartum therapeutic costs, and drug costs for $PGF_{2\alpha}$ across all treatments. Because the potential savings in labor costs for the producer are herd specific, they were not considered. The SI treatment cost $3.61 less per cow than the RP treatment and saved 6 median d open per cow (an additional $12 per cow) compared with RP treatment.

Sensitivity analysis on the partial budget suggested that the decision to use a scheduled interval $PGF_{2\alpha}$ program, such as SI, in a herd would consider economic return of an improved reproductive efficiency (e.g., higher pregnancy rate) in the herd compared with additional drug costs incurred for the program. The benefits of the SI treatment may be less pronounced in herds with either excellent efficiency or poor accuracy of estrus detection and low conception rates.

CONCLUSIONS

This study evaluated the reproductive performance and net economic benefit of using $PGF_{2\alpha}$ as a postpartum therapeutic and tool for detection of estrus. The PG program was less expensive and resulted in reproductive performance equivalent to that of a RP program based on veterinary intervention. With the SI program, reproductive efficiency and net economic benefit were improved over that of a traditional RP program. The improved reproductive performance associated with an SI program was directly attributed to greater synchronization of estrus, which improved efficiency of detection, rather than to postpartum therapeutic effects of $PGF_{2\alpha}$. The overall results of this study suggest that a PG program in which $PGF_{2\alpha}$ is used at scheduled intervals is cost effective and may improve herd reproductive performance compared with more traditional programs.

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