Reproductive Program Aids–Beneficial or Band Aid?

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Introduction

Management of reproduction of dairy cows in high milk-producing herds was recently reviewed (Stevenson, 2001). Reproductive inefficiency of dairy cattle causes great frustration for dairy producers (Call and Stevenson, 1985). Even under optimal conditions, the reproductive process is less than perfect because of the multiple factors involved in producing a live calf. To manage the complexities of the estrous cycle and the annual reproductive cycle, understanding of many interrelated physiological functions is critical. Further, reproductive efficiency involves successful management of not only the cows but also the people who milk, feed, house, inseminate, and care for them.

Conception rates of lactating dairy cows in the U.S. have declined since the 1950's (Butler and Smith, 1989), whereas annual milk yield per cow has increased 3.3 times from 2410 to 8061 kg. Based on a sample of dairy cows in the U.K., fertility declined from 1975-1982 to 1995-1998 (Royal et al., 2000). During that period, pregnancy rates after first services decreased from 56 to 40% despite similar intervals to first service, whereas calving intervals increased from 370 to 390 d. Given the inverse relationship between milk yield and fertility (Macmillan et al., 1996), it is no wonder that a genetic antagonism exists between some reproductive traits and milk yield, which is manifested particularly in primiparous cows (Hansen et al., 1983). However, sound management practices have overcome this inverse relationship to achieve acceptable rates of reproductive efficiency (Laben et al., 1982).

Efficient reproduction in a dairy herd is the primary determinant of profitability (Call, 1978). Although the benefits of improving reproduction are apparent, specific causes of poor reproductive performance are difficult to identify and not resolved easily. To improve reproductive efficiency, the limiting factors must be identified. In general, detecting estrus is the major limitation to achieving a pregnancy (Barr, 1975). But once insemination occurs, two sources of pregnancy failure exist, which include, but are not limited to, fertilization failure and embryonic death. Fertilization failure follows procedures or practices that fail to facilitate union of a viable egg with a viable sperm. Once fertilization occurs, embryonic death results from failure of normal embryonic development, recognition of pregnancy, or normal maintenance of pregnancy.

To maximize the chances of a renewed pregnancy for every heifer or cow that calves into the herd, a number of important time-dependent components of the estrous cycle must be managed. It is critical to understand each component of the estrous cycle as well as the annual reproductive cycle (calving interval) and determine where limited time and resources might be concentrated best to reach AI-breeding goals. Maximal reproductive efficiency requires management of the calving interval. This consists of three major components: the 1) volunteer waiting period (VWP), 2) the active AI-breeding period, and 3) gestation (including the dry period) plus their various integral parts (Figure 1).

AI-Breeding Period

Programmed Breeding.

Development of programmed breeding systems is judged to be highly beneficial to the management of reproduction of dairy cows because it is a method to schedule and control the insemination program of lactating cows in the herd. The advantages for programming estrous cycles include: 1) convenience of scheduling labor and tasks; 2) controlling the occurrence of estrus, ovulation, or both; and 3) knowing the stage of the estrous cycle and reproductive status of groups of cows in the herd. These reproductive statuses include: 1) open cows scheduled for first services; 2) open cows scheduled to be reinseminated; 3) open cows designated as culls; and 4) cows confirmed pregnant. Therefore, programmed breeding can be applied to at least two distinct groups of cows: 1) those that are scheduled for their first postpartum inseminations and 2) those that are open at pregnancy diagnosis but are reprogrammed to be inseminated in a new breeding cluster.

***Breeding Clusters*.**

The breeding cluster is one method that can be used to organize groups of cows for programmed breeding (Folman et al., 1984). For example, if the VWP is 50 d before scheduled AI, then a breeding cluster of cows can be organized to fall within a certain range of days in milk to fit the targeted first breeding date. These cows can be identified easily using DHIA software, computer records, or spreadsheet programs, or simply by keeping a chronological list of calving dates. In a herd of 200 cows, a cluster that calves during a 3-wk period can be organized so the freshest cow in the cluster meets the minimum acceptable VWP at the time of AI. When the VWP is 50 d, a cluster would consist of cows that are 50 to 70 d in milk during the targeted breeding week. Therefore, the average interval to first insemination for that cluster would be 60 d. Cows failing to conceive should return to estrus during the breeding week of the next cluster of cows, which would be estrus-synchronized for AI 3 wk after the first cluster. This clustering method allows first services and repeat inseminations to occur during the same week, thus concentrating most inseminations during 1 wk out of every 3 wk.

In large herds (>200 cows), grouping cows into 1- or 2-wk clusters is recommended. These clusters reduce the number of cows that meet the breeding criteria on a weekly or biweekly basis, but increase the complexity of scheduled treatment injections with as many as three clusters treated per Monday or Wednesday for weekly clusters. Therefore, during the period before the cows reach their targeted breeding date (based on days in milk and the VWP), estrus or ovulation is synchronized to occur during each breeding week. Usually, the synchronization period is set so estrus or a fixed-time insemination (timed AI [TAI]) occurs during the Monday-to-Friday work week or at the convenience of scheduled labor.

Once a system is in place to identify cows that satisfy those criteria for inclusion in an AI-breeding cluster, then the specific programmed breeding system can be fit into a weekly management sequence. At least five programs are commonly in use on the U.S. dairy farms: 1) Targeted Breeding™; 2) Modified Targeted Breeding; 3) Ovsynch™; 4) Heatsynch; and 5) Presynch + Ovsynch.

***Targeted Breeding™ Program*.**

This program was promoted by one of the PGF_{2a} manufacturers (Pharmacia Animal Health) for synchronizing the AI breeding of lactating cows in a herd (Figure 2; Nebel and Jobst, 1998). Injections of PGF_{2a} are administered 11 to 14 d apart. This interval is based simply on the fact that sufficient time must pass after the first injection so those females responding to the first injection (their corpus luteum [CL] regresses and they come into estrus) have a new CL that is mature enough to respond to a second injection (at least on d 6 of the estrous cycle). In addition, those females that were not in a stage of the estrous cycle with a CL that could regress after the first PGF_{2a} injection should be responsive 11 to 14 d later (Odde, 1990; Beal, 1998). Targeted breeding requires that the first injection (so-called set-up injection) be given 14 d before the VWP ends. No cows are inseminated after the first injection, although up to 50% may show estrus in response to it. The second injection (first breeding injection) then is given just before the end of the VWP, so first services can occur when cows are eligible for AI breeding. The Targeted Breeding program then recommends that when no estrus is detected after the second injection, a third injection (second breeding injection) be given 14 d after the second injection. If no standing estrus is detected after this third injection, then one TAI can be given at 72 to 80 h after this third injection of PGF_{2a} (Figure 2).

***Modified Targeted Breeding Program*.**

The Modified Targeted Breeding program also was promoted by Pharmacia Animal Health for synchronizing the AI breeding of lactating cows in a herd (Figure 3). This program was designed to force the majority of cows into the early luteal phase of the estrous cycle with a presynchronizing injection of PGF_{2a} before the administration of GnRH. Then a 100-µg injection of GnRH is given 7 d before a second PGF_{2a} injection. The GnRH injection alters follicular growth by inducing ovulation of the largest follicle (dominant follicle) in the ovaries to form a new or additional CL (Pursley et al., 1995). Based on random distribution of cows throughout the estrous cycle, about 64% will be at a stage of the cycle in which a dominant follicle will ovulate in response to the GnRH-induced LH release from the pituitary gland (Vasconcelos et al., 1999). Thus, estrus usually does not occur until after a PGF_{2a} injection regresses the natural CL, the GnRH-induced CL (formed from the follicle induced to ovulate by the first GnRH injection), or both. Therefore, a new group of follicles emerges from the ovaries (as shown by transrectal ultrasonography) within 1 to 2 d after the first injection of GnRH (Pursley et al., 1995). From that new group of follicles, a newly developed dominant follicle emerges, matures, and ovulates after estrus is induced by PGF_{2a}. Following the PGF_{2a} injection, cows are inseminated based on detected estrus, or in the absence of estrus, one timed AI (TAI) can be administered at 72 to 80 h after PGF_{2a}.

Ovsynch.

This program is by far more popular than the previous program, except it requires no detection of estrus (Figure 4). In fact, it is described more accurately as an ovulation synchronization program; hence the name, Ovsynch. A 100-µg injection of GnRH is given 7 d before a PGF_{2a} injection, then a second 100-µg injection of GnRH is administered 48 h after PGF_{2a}, with one TAI given 0 to 24 h later. A recent study reported no difference in pregnancy rates when 50 vs. 100 µg of GnRH was injected at either time (Fricke et al., 1998). Following the first GnRH injection, a dominant follicle is induced to ovulate as described previously. Following the second GnRH injection, in the absence of elevated concentrations of progesterone after CL regression is induced by PGF_{2a}, the preovulatory LH surge is induced so the preovulatory follicle ovulates between 24 and 34 h later (Pursley et al., 1995). Few cows will show estrus in this program, with about 8 to 16% around the time of the PGF_{2a} injection and up to 30% by or shortly after the second GnRH injection (Stevenson et al., 1999). If cows are detected in estrus at any time, they should be inseminated according to the AM-PM rule (Trimberger, 1948) to maximize conception, and the injections of PGF_{2a}, GnRH, or both should be eliminated.

Heatsynch.

The Heatsynch program (Figure 5) has evolved from the Ovsynch protocol where the second GnRH injection at 48 h after PGF_{2a} is replaced by a 1-mg injection of estradiol cypionate (ECP) at 24 h after PGF_{2a}. Cows begin to come into heat by 24 h after ECP and AI-breeding should be conducted according the AM-PM rule (Trimberger, 1948), with the residual receiving a TAI at 48 h after ECP. Comparisons of Ovsynch to Heatsynch show little differences in fertility (Pancarci et al., 2002).

Presynch + Ovsynch.

Further research with the Ovsynch protocol revealed that when cows were started on this protocol between d 5 and 12 of the estrous cycle, diameter of the ovulatory follicle was less but conception rates tended to be greater than at other stages of the cycle (Vasconcelos et al., 1999). At least three experiments have demonstrated improved fertility in cows when one PGF_{2a} injection was given 12 d before initiating the Ovsynch protocol or two injections were given 14 d apart, with the second injection given 12 d before the onset of the Ovsynch protocol. In those studies, pregnancy rates of multiparous cows were increased by 13 percentage points with one injection of PGF_{2a} preceding the Ovsynch protocol, (Cartmill et al., 2001a), whereas pregnancies were improved by 12 to 14 percentage points in all lactating cows with two injections of PGF_{2a} (Moreira et al., 2001; El-Zarkouny et al., 2002). The so-called Presynch procedure entails two injections of PGF_{2a}, given 14 d apart with the second injection given 12 d before initiating the Ovsynch protocol (Figure 6). Presynch + Heatsynch works in a similar fashion to the combination with Ovsynch. Combining the initiation of bST with the initiation of Ovsynch was found to improve pregnancy rates after Ovsynch compared to controls not treated with bST (Moreira et al., 2000).

Advantages of Various Programs.

Table 1 summarizes the advantages of the four programmed breeding systems described above. The best program should be simple and easy to manage, perceptions that may vary with personalities and skills of personnel for each herd. Simplicity could be defined as handling cows fewer times during the synchrony program. Some studies show that conception rates are greater when cows are inseminated after a natural estrus compared to a TAI (Burke et al., 1996; Stevenson et al., 1996; Jemmeson, 2000), whereas others detected no differences (Pursley et al., 1997a,b;

Cartmill et al., 2001b). Few comparisons of programmed-breeding systems have been made in field trials (Nebel and Jobst, 1998). Pregnancy rates achieved in several herds after the Targeted Breeding and Ovsynch programs were similar for lactating cows, but less for replacement heifers on the latter program (Pursley et al., 1997b). Both programs improved reproductive performance over traditional programs (Nebel and Jobst, 1998) and decreased days open compared to no hormonal intervention (Keister et al., 1999).

The important point is not the comparison of conception rates, but whether one program produces more pregnancies per unit of time (pregnancy rate) compared with another. If conception rates are similar, pregnancy rates will be greater when TAI is used because the AI submission rates are 100%. Therefore, all programs described except the Targeted Breeding program have the TAI component. That program requires considerably more time to administer, including the need for detection of estrus. Where skilled cow people are involved and are adept in detecting subtle as well as major symptoms of estrus, the Targeted and Modified Targeted Breeding programs may be successful. The disadvantage of any system is the rigidity of the injection schedules to which one must conform to guarantee its success.

What adds to the complexity of these systems is the overlapping nature of the cluster groups. For example, if the Presynch + Ovsynch protocol is followed where a new cluster is initiated every 2 wk, injections must be given concurrently to three different cluster groups. Further, if pregnancy is diagnosed once weekly and open cows are started in their own separate cluster group, the complexity of more cluster groups increases (Figure 1). In almost every case, personnel must be disciplined and detailed in their approach to making these programs work. Otherwise, the alternative is few pregnancies achieved and high culling rates of open cows. As herd size increases and more cows are confined to concrete, the efficiency of detected estrus will decline, because the number of standing events and duration of estrus are less on concrete where footing is not as good as it is on dirt (Britt et al., 1986; Vailes and Britt, 1990). As a result of less inefficient detection of estrus or the lack of expressed estrus by cows in environments with poor footing, TAI programs will become more popular because of their predictability and manageability and likely produce a greater proportion of the total pregnancies of dairy cows in the future.

Costs of Programmed Breeding

Assessing the costs of using programmed AI-breeding is not easy. Further, most producers assume that it is more costly because of the extra labor, semen, and hormones. Table 2 summarizes how programmed breeding can be economically beneficial. A comparison is made between the Ovsynch protocol and a program that is dependent on detected estrus, with or without hormonal intervention. The total cost of Ovsynch is about $38 ($13 for the three injections, $5 for labor to administer injections, $15 for semen, and $5 for AI-breeding). That compares to $20 (semen + AI-breeding) for the traditional approach. If we assume that conception rate is 40% in both cases, then at a 70% heat detection rate, the traditional program would produce 28 pregnancies (70% x 40%) and Ovsynch would produce 12 more pregnancies or 40 in total.

To determine the value of those 12 pregnancies, the value of one pregnancy must be estimated after the cow already has failed to conceive once. It takes about 63 d to impregnate a cow (pregnancy rate of 28% per 21-d cycle), so at only $1 per day (Stevenson and Pursley, 1994), the pregnant cow has a $63 greater value than the nonpregnant cow. At a conception rate of 40%, each open cow will require 2.5 more doses of semen + AI labor or $50 more per pregnancy. Assuming that 20% of the cows will fail to conceive, the cost of a replacement heifer is $1200, and the value of a cull cow is $500, then $140 ($700 x 20% culls) must be added. So one additional pregnancy is worth $253 ($63 + $50 + $140). Because those 12 additional pregnancies cost $200 each, a positive return on investment occurs ($53 per additional pregnancy).

However, if estrus detection is closer to 50% as in most herds, then only 20 pregnancies are achieved in 21 days and that is 20 fewer than what is achieved with Ovsynch. Each of those pregnancies would cost only $140 ($3800 Ovsynch costs - $1000 traditional costs/20). Because of poorer heat detection, it will take one more estrous cycle or a total of 84 days to get 80% of the remaining cows pregnant, so the value of a pregnant cow is $84 more than that of the open cow. The costs of semen, AI-breeding, and culling are the same, so the value of one additional pregnancy at a 50%-heat detection rate is $274 ($84 + $50 + $140). Thus the cost of $140 per each additional pregnancy gained by Ovsynch gives a positive return of $134 per additional pregnancy. Clearly, Ovsynch or other programmed AI-breeding systems pay for themselves, because more cows become pregnant per unit of time. Even though more costs are associated with their use, the return on investment is greater. Based on these cost estimates, as heat detection, conception rates, or both decline, the programmed AI-breeding (in this case, Ovsynch) provides greater economic return.

Active AI-Breeding Period

The second component of the calving interval is the period of time between the end of the VWP and when the first or subsequent estrus is detected followed by AI and eventual conception (Figure 1). The duration of this period is a function of the estrus-detection rate and the level of individual cow fertility. Whether or not hormones are used to induce estrus before first and subsequent services, the percentage of cows detected in estrus depends on the efficiency of detecting estrus in all cows (Stevenson, 2000). The level of cow fertility depends upon a number of factors, including the fertility of the service sire, correct thawing and handling of semen, AI-breeding technique, and timing of insemination (Stevenson et al., 1983). Level of fertility and estrus-detection rates are rate limiting to the establishment of pregnancy in a timely fashion.

Detection of Estrus

The greatest limiting factor to successful fertilization is detection of estrus. Approximately 50% of the estrous periods go undetected on the average dairy farm in the U.S. (Barr, 1975). This figure is likely greater than what occurs on large dairy farms today because of the conspicuous absence of any regular routine visual observation for estrus. Two important challenges exist for detecting estrus: accurately recognizing signs of estrus and identifying all possible periods of estrus in breeding heifers and cows. One might be quite accurate in detecting cows in estrus but still have a major estrus-detection problem because too many estrous periods go unobserved. Problems are caused by a lack of diagnostic accuracy (errors of commission) and a lack of efficient detection of all periods of estrus (errors of omission). Based on elevated progesterone on the day of AI, detection errors of commission averaged 5.1% (Reimers et al., 1985) and 13% (Anon, 1992) and ranged from 2 to 60% in some herds. The value of improved estrus detection was estimated to range from $6 to $83/yr when the probability for increasing estrus detection increased from 60 to 70% or from 20 to 30%, respectively (Pecsok et al., 1994a). The wide range of values occurred with fixed costs and prices so that fluctuating prices, would introduce further variation in the financial benefits.

Is detection of estrus more difficult in higher milk-producing herds? Surveys of DHI data usually find that herds with greater rolling herd averages for milk also have greater rates of detected estrus (Heersche and Nebel, 1994). Further, in a few studies in which estrus-detection rates and milk production have been reported, the results are equivocal (Fonseca et al., 1983; Harrison et al., 1990; Hageman et al., 1991). Anecdotal observations indicate that higher producing cows are more difficult to detect in estrus. However, because movement of more cows into confinement has occurred concomitantly with increased milk yield, current estrus-detection rates with less than ideal footing conditions (Britt et al., 1986) and increased milk yield per cow are confounded. Research is warranted to determine whether increased production *per se* has reduced rates of detected estrus.

Signs of Estrus

A cow will not be detected to stand if no other cow is available to mount. Mounting activity is stimulated strongly by estrogen and inhibited by progesterone (Allrich, 1994). Thus, mounting frequency is considerably greater for cows in proestrus or estrus than for cows that are out of estrus or in midcycle with a functional CL (Helmer and Britt, 1985). Once four or more sexually active animals are in estrus in the same pen, standing and mounting activity normally will be maximized (Hurnik et al., 1975) and should increase efficiency of detected estrus. For that reason, if no synchronization of estrus or ovulation is used, no fewer than 20 nonpregnant cows should be penned together to maximize the efficiency of detected estrus.

A number of environmental conditions either stimulate or restrict interactions among cows and influence whether they show estrus (Stevenson, 2000). Cows that are eating or are crowded in holding pens or alleys do less mounting.

Cows also show less mounting activity when housed on slippery alleys, frozen ground, or any surface that makes footing tenuous (Britt et al., 1986). Cows in estrus are more likely to mount one another if the other cows are loose rather than tied. Perhaps this indicates that freedom to interact before mounting is important for maximum expression of mounting activity. Cows that have foot problems show less mounting activity regardless of whether the problem is structural, subclinical, or clinical (Leonard et al., 1994). Many of the foot problems that affect mounting activity might be alleviated by proper foot care (e.g., foot baths or keeping dry cows on dirt) and regular hoof trimming.

Estrus-Detection Aids

Senger (1994) described the ideal estrus-detection system as having the following characteristics: 1) continuous surveillance of the cow; 2) accurate and automatic identification of the cow in estrus; 3) operation for the productive lifetime of the cow; 4) minimal labor requirements; and 5) high accuracy and efficiency (95%) for identifying the appropriate physiological events that correlate with estrus, ovulation, or both. Several estrus-detection aids are available on the market to assist dairy producers in identifying estrus (Stevenson, 2000). These include inexpensive tail paints, tail chalks, heat mount detectors such as the Kamar® or Bovine Beacon® and more expensive electronic gadgetry including pedometers, which measure increased physical activity (walking) associated with estrus or pressure-sensitive, and rump-mounted devices such as the HeatWatch® system, which detects and records standing activities by cows in estrus. Further, biochemical prototype sensors that are able to measure progesterone in-line during the milking procedure have been tested (Koelsch et al.,1994; Claycomb et al., 1996). Generally, to date none of these estrus-detection devices is more accurate in detecting estrus than visual observation but they usually are more efficient (Stevenson, 2000). That is, they detect more estrual activity because they are always "on-the-job" when no one may be watching cows. When used properly as a supplement to visual observations, estrus-detection aids have a useful role in those cows in which estrus is more difficult to detect (i.e., cows that are not yet inseminated or inseminated but still not pregnant).

Cows Not Pregnant at Pregnancy Diagnosis

To promptly reinseminate nonpregnant cow once diagnosed open, the traditional procedure was to give a PGF_{2a} injection to any cow with a palpable CL. Cows were either inseminated based on subsequently detected estrus or inseminated once (80 h; Elmarimi et al., 1983) or twice (72 and 96 h; Plunkett et al., 1984) after PGF_{2a}. Because inseminations are based only on detected estrus, some open cows may go without reinsemination for weeks. The Ovsynch or Heatsynch protocols are ideal for preparing open cows for reinsemination (Figures 1, 4, and 5). The key benefit of these programs is that the AI resubmission or reinsemination rates are increased compared to relying solely on heat detection. These programs guarantee that every cow is reinseminated within 9-10 d after nonpregnancy status is identified (Bartolome et al., 2002), with little difference in the pregnancy outcomes from the two protocols. If the open cow is detected in estrus at any time during the 10-d protocol (Figure 7), then the cow should be inseminated according to detected estrus and the remaining portions of the protocol discontinued. Using this system, detection of estrus can be eliminated totally, but inter-insemination intervals will average 50 d (time to pregnancy diagnosis + 10 d for the Ovsynch protocol) rather than multiples of one estrous cycle depending on the rate of detected estrus in the herd. Abbreviated resynchronization programs using PGF, GnRH, or both after an early nonpregnant diagnosis on d 28-30 after TAI are successful in reducing days to conception with conception rates at the resynchronized estrus or ovulation equal to those in controls (Stevenson et al., 2003).

Resynchronization of Estrus in Cows of Unknown Pregnancy Status

Reapplying a used progesterone-releasing intravaginal insert (controlled internal drug releasing [CIDR] insert) by itself for 7 d or in combination with an estrogen injection at CIDR insert and at its removal (or 24 h after its removal) can resynchronize the first eligible estrus following a previous insemination (Macmillan et al., 1999; El-Zarkouny et al., 2001; 2002). Using such techniques the pregnancy established following the initial insemination is not harmed and conception rates at the detected estrus following resynchronization may be normal or reduced in magnitude relative to controls.

Another proactive technique of resynchronization calls for injection of GnRH at 21 days after a previous insemination, followed in 7 d by ultrasonography for pregnancy diagnosis. Nonpregnant cows then receive PGF_{2a} followed in 48 h by GnRH and timed AI (Chebel et al., 2002). Conception rates did not differ from controls.

Timing of Ovulation and Insemination

The key to proper timing of insemination and maximizing fertilization rates is to inseminate cows at a time to allow ovulation to occur when adequate numbers of motile sperm are present in the oviduct. Based on a twice-daily, estrus-detection program, cows submitted for insemination should be inseminated about 12 h after first detection in estrus (Trimberger, 1948). The exact time when estrus begins is unknown, but on the average, the female detected in estrus at either daily observation period has been in estrus for about 6 h. So when inseminated 12 h after first detection, the female actually is bred about 18 h after the onset of estrus or approximately 6 to 12 h before ovulation. This breeding scheme allows ample time for transport and capacitation of sperm and a synchronized overlap of the fertile lives of both the egg and the sperm, even if the timing is off by as much as 6 h. Conception rates were greater for cows that were in estrus during the morning and inseminated the same afternoon (52%) than for cows observed in the afternoon and serviced the next morning (47%; Reimers et al., 1985). In contrast, other studies, which were based on nonreturn rates, have shown that conception rates after once daily AI were not different from those for cows inseminated based on the AM-PM rule (Foote, 1979; Nebel et al., 1994). Results were best when inseminations were based on standing estrus and when AI occurred between 8 and 11 AM (Nebel et al., 1994). Optimal timing of AI should occur between 4 and 12 h after the first standing event detected by the HeatWatch® system (Dransfield et al., 1998) or between 6 and 17 h after increased pedometer readings (Maatje et al., 1997).

Based on elevated progesterone on the day of AI, 5.1% (Reimers et al., 1985), 13% (Anon, 1992), or 19% (Sturman et al., 2000) of cows are inseminated when not in estrus. Inseminating pregnant cows can lead to induced embryonic death or abortion. Approximately 10% of pregnant dairy cows express estrus (Erb and Morrison, 1957). To avoid aborting a previous pregnancy in these cows, semen should be deposited midcervically (Macmillan et al., 1977), thereby reducing the potential for aborting a pregnancy but still giving the cow a chance to conceive if she is open and really in estrus. More careful submission and rejection of questionable previously inseminated cows can reduce unnecessary use of semen, reduce abortions, and minimize long calving intervals (Sturman et al., 2000). Increased induced abortion of pregnant cows may be occurring today because of too heavy reliance on "reading" tail chalk as the sole means of detecting estrus.

AI Techniques

Actual insemination technique may or may not be a major factor contributing to failure of fertilization. Improper placement of the semen in the reproductive tract can be a limiting factor when the technician is unsure where the tip of the breeding gun is placed upon deposition of semen. Fewer numbers of motile sperm gain access to the oviduct when semen is placed in the cervix than in the uterus (Hawk, 1983). The target for insemination is the uterine body. When in doubt, deposition of the semen slightly inside one or both uterine horns is less likely to compromise fertility than placement only in the cervix. Inseminations into the uterine body or both uterine horns produced similar nonreturn rates (McKenna et al., 1990). Because most of the inseminate is expelled from the female by retrograde flow (Hawk, 1983), it is critical that all of the semen be placed in the uterus. Errors in semen placement are common among professional technicians. Below-average technicians placed the inseminate in the target site (body of uterus) only about one-third of the time compared to 85.7% accuracy by above-average technicians (Graham, 1966). Nearly 25% of the time, semen was not even placed in the uterus by below-average technicians. Few cows will conceive when the semen is placed in the vagina.

Conclusions and Perspectives

- Components and parts of the calving interval outlined in Figure 1 illustrate the key management steps in maintaining reproductive efficiency in the dairy herd.
- Efforts must be focused to maximize the number of pregnancies achieved per unit of time. Achieving 10% of the lactating cows pregnant per month is a realistic goal.

- Use of programmed breeding systems has improved first-service submission rates and uniformity of intervals to first service. They are a welcome band aid for lack of consistent, routine heat detection.
- Presynch + Ovsynch or Presynch + Heatsynch programs are likely to be the most efficient and least costly way to prepare clusters of cows for their best chance to conceive at first AI service. They are extremely beneficial tools.
- Combining bST treatment of cows with the onset of the Ovsynch protocol increased fertility of cows compared to non-bST-treated cows treated with Ovsynch.
- Heat detection by visual means is a lost art in large dairy herds. Use of tail chalk has become the most commonly used "heat-detection" technique. It is often highly inaccurate and over-rated as an accurate method of detection. It likely perpetuates the reinsemination and abortion of pregnant females.
- Other more sophisticated electronic detection aids to identify normal returns to estrus at 18 to 24 d after TAI would ensure greater return rates of cows not pregnant to the first TAI.
- Few cows returning to estrus after AI (including some so-called "phatom" cows that do not express signs of estrus at the first eligible estrus after AI, but are found not pregnant at pregnancy diagnosis) is a problem because intensity of estrus at a repeat estrus is less after they are once inseminated (Richardson et al., 2002).
- For those open cows not detected in estrus, weekly pregnancy diagnosis by ultrasonography or palpation is critical to resynchronize open cows by applying a program such as the Ovsynch or Heatsynch to guarantee reinsemination by 9-10 d after open diagnosis. Biweekly or monthly pregnancy diagnosis is too infrequent to allow prompt reinsemination of open cows.
- Methods for resynchronization of estrus (CIDR or CIDR + estrogen injections) in previously inseminated cows of unknown pregnancy status are promising for further reducing inter-insemination intervals.
- Pregnancy should be reconfirmed at approximately 90-100 d, because most pregnancy loss occurs between 28 and 98 d after conception (Vasconcelos et al., 1997).
- Costs of a pregnancy are estimated to be $250 to $300 each (Table 2). Some AI organizations have programs in place in which they contract with dairy producers to produce pregnancies at similar amounts. In those cases, the entire AI program is turned over to the AI company technicians.
- Factors governing reduced reproductive performance in dairy cattle are numerous and often difficult to diagnose. In general, those factors resulting from inadequate detection of estrus or fertilization failure (e.g., semen handling, and AI techniques) are resolved more easily than those related to embryonic death.
- Detection of estrus and timing of insemination require more labor and common sense, they are more manageable than many causes of embryonic death.
- Diagnosing causes of embryonic death may be difficult because they usually are related to some source of stress experienced by the lactating cows.
- A continuous effort should be focused on increasing comfort and reducing various stressors that undoubtedly lower reproductive efficiency.

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Table 1. Advantages of various programmed-breeding systems

	Programs			
Item	TB[1]	Modified TB	Ovsynch	Presynch + Ovsynch
Simplicity		X	X	
Greatest conception rates[2]	X	X		
Greatest pregnancy rates[3]			X	X
Herd size	X	X	X	X
No detection of estrus			X	X
Shorter time of program administration		X	X	
Synchronizes follicle growth and CL regression		X	X	X
Timed insemination without detection of estrus			X	X

[1]TB = Targeted Breeding

[2]Conception rate = no. of pregnant cows divided by the number of cows inseminated.

[3]Pregnancy rate = no. of pregnant cows divided by the number of cows treated. When timed AI is used and the AI-submission rate is 100%, then conception rate = pregnancy rate.

Table 2. Comparison of AI-Breeding Costs of Ovsynch and a Traditional Heat Detection Program without Hormonal Intervention[1]

Per Cow	Traditional	Ovsynch
Hormones[2], $	0	13
Labor, $	20	5
Semen + AI[3], $	20	20
Total costs, $	20	38

Per 100 Cows	Estrus-detection rate		AI submission rate	
No. of cows inseminated	50	70	100	100
No. of pregnancies[4]	20	28	40	40
Cost for 100 cows[5], $	1000	1400	3800	3800
Cost per pregnancy[6], $	50	50	95	95
Increased no. of pregnancies by Ovsynch[7]			+20	+12
Total cost of additional pregnancies[8], $			2800	2400
Per cow cost of additional pregnancies[9], $			140	200
Value of additional pregnancy[10] $			274	253
Semen + AI labor, $			50	50
Additional days open at $1 per day			84	63
Replacement cost, $			140	140
Net return per additional pregnancy, $			+134	+53

[1]Adapted from Gardner (1998).

[2]Cost of $PGF_{2?}$ = $3 and two doses of GnRH = $5.

[3]Cost of semen = $15 and insemination = $5.

[4]No. of pregnancies or pregnancy rate = estrus-detection rate ? conception rate (40%).

[5]No. inseminated (50, 70, or 100) ? cost per cow.

[6]Cost per 100 cows divided by the number of pregnancies.

[7]Compared to 50% and 70% heat detection rates, respectively.

[8]Difference in cost for the traditional and Ovsynch programs at each estrus-detection rate.

[9]Cost of additional pregnancies divided by the number of pregnancies.

[10]Cost of 2.5 more services (40% conception rate) + average of 63 or 84 days open to impregnate successfully 80% of the 12 or 20 remaining open cows (not pregnant after first service in the traditional program), respectively, plus the cost of replacing 20% of open cows with replacements valued at $1200 each and cull cows worth $500.

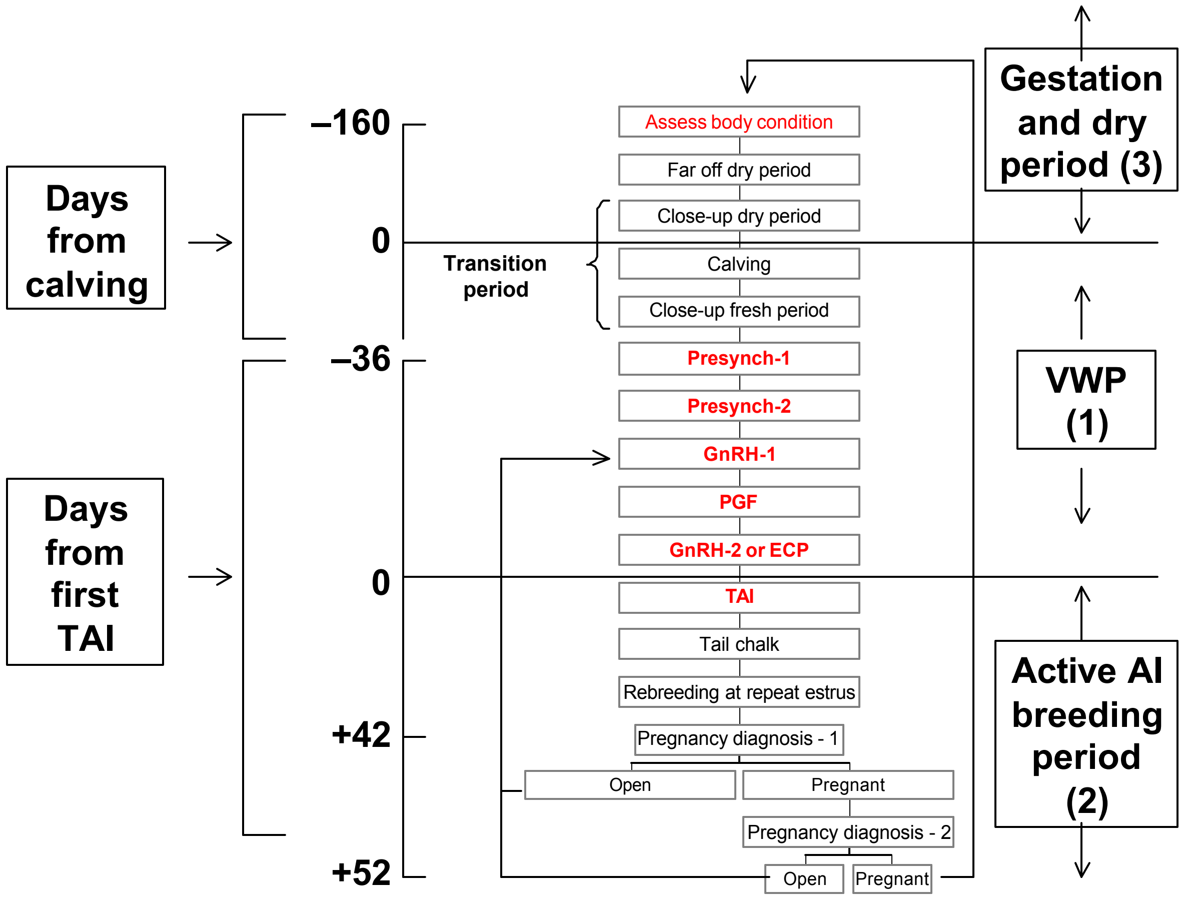

Figure 1. Components of a calving interval consisting of 1) the volunteer waiting period (VWP); 2) the active AI-breeding period; and 3) gestation and the dry period. Various management elements are illustrated that lead to reproductive management and programming of the annual reproductive cycle or calving interval.

Week	M	T	W	Th	F	S	S
1	PGF	No AI					
2							
3	PGF	Detect estrus - AI					
4							
5	PGF	Detect estrus - AI					

← 80 h → TAI

Figure 2. Injection schedule for the Targeted Breeding? program.. Injections of PGF_{2a} are administered 14 d apart and inseminations occur after the second and third injections according to detected estrus. When no estrus is detected after the third injection, one timed AI (TAI) can be given 80 h later.

Week	M	T	W	Th	F	S	S
1	PGF						
2							
3	GnRH						
4	PGF	Detect estrus + AI					

← 80 h → TAI

Figure 3. Injection schedule for the Modified Targeted Breeding program. Injection of PGF_{2a} is given 14 d before gonadotropin-releasing hormone (GnRH) to increase the proportion of cows in the early luteal phase of the estrous cycle before GnRH. An injection of PGF_{2a} is administered 7 d after GnRH, and then cows are inseminated according to detected estrus. If no estrus occurs, one timed AI (TAI) can be given 80 h after PGF_{2a}

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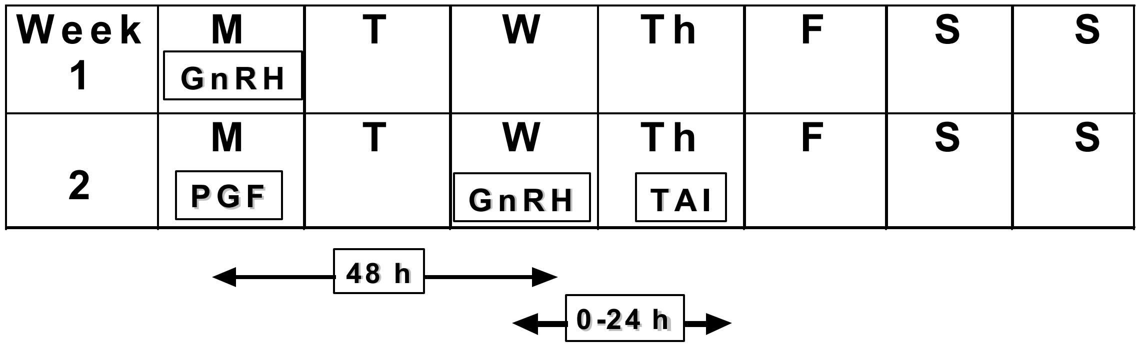

Figure 4. Injection schedule for the Ovsynch protocol. Injections of gonadotropin-releasing hormone (GnRH) are administered 7 d before and 48 h after PGF_{2a}. Cows are inseminated between 0 and 24 h after the second GnRH injection.

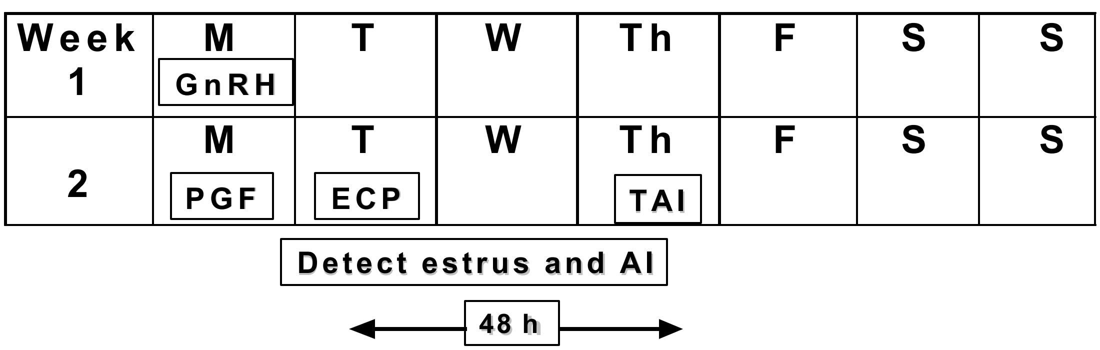

Figure 5. Injection schedule for the Heatsynch protocol. An injection of gonadotropin-releasing hormone (GnRH) is administered 7 d before PGF_{2a}, followed in 24 h by 1 mg of estradiol cypionate (ECP). Cows are inseminated based on signs of observed estrus and the residual receive one TAI 48 after ECP.

Week	M	T	W	Th	F	S	S
1	M	T	W PGF	Th	F	S	S
2	M	T	W	Th	F	S	S
3	M	T	W PGF	Th	F	S	S
4	M	T	W	Th	F	S	S
5	M GnRH	T	W	Th	F	S	S
6	M PGF	T	W GnRH	Th TAI	F	S	S

← 48 h →

← 0-24 h →

Figure 6. Injection schedule for the Presynch protocol that precedes the Ovsynch protocol. This protocol is similar to the Ovsynch protocol except that two injections of PGF_{2a} are administered 14 d apart with the second injection given 12 d before initiating the Ovsynch protocol. The purpose of the PGF_{2a} injections is to group cows into the early luteal phase of the estrous cycle at the onset of the Ovsynch protocol.

Week	MON	TUE	WED	THU	FRI	SAT	SUN
1	GnRH						
2	PGF		GnRH	TAI			
7	33 d GnRH						
8	40 d Preg. Ö: Open? GnRH or PGF		GnRH	TAI			
9	PGF		GnRH	TAI			

Figure 7. Programmed reproductive management without detection of estrus can occur when using the Ovsynch or Presynch + Ovsynch protocols. When cows are diagnosed open based on weekly Monday morning palpation, all nonpregnant cows are restarted on the Ovsynch protocol and thus time-inseminated 10 d after their nonpregnancy status is identified. Alternatively, all cows of unknown pregnancy status receive an injection of GnRH 7 d before pregnancy diagnosis. Cows identified as not pregnant complete the Ovsynch protocol by receiving PGF_{2a} at open diagnosis followed in 48 h by GnRH and TAI.