

Ovsynch, Pre-synch, the Kitchen-Synch: What's up with Synchronization Protocols?

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Take Home Messages and Terminology

- Basic research on the nature of follicular growth and regression in cattle using transrectal ultrasonography lead to the discovery of **follicular waves**. A thorough understanding of the processes of follicular and luteal growth in cattle was the first step toward development of practical management strategies for controlling the reproductive cycle in cattle.
- Synchronization of estrus using **PGF_{2α}** is an effective strategy if cows are subsequently detected in heat and inseminated. However, a timed artificial insemination (TAI) after PGF_{2α} in the absence of a detected estrus results in poor conception rates because PG F_{2α} controls luteal regression but not follicular growth.
- **Ovsynch** uses PGF_{2α} and GnRH to synchronize ovulation in lactating dairy cows. Ovsynch was the first synchronization protocol developed that allowed for a TAI resulting in conception rates similar to that of AI after a detected estrus.
- **Co-Synch** is a specific form of Ovsynch in which the TAI occurs at the time of the second GnRH injection. The advantage of Co-Synch is that one less handling is required for each cow compared to Ovsynch; the disadvantage of Co-Synch is that conception rates may not be optimized compared to TAI at 12-18 h after Ovsynch.
- **Pre-Synch** is a modification of Ovsynch in which two PGF_{2α} injections 14 days apart are administered 12 to 14 days before initiation of the first GnRH injection of Ovsynch. Pre-Synch improves first service conception rate compared to Ovsynch and is a good strategy for programming cows to receive their first postpartum TAI.
- **Heat-Synch** is an alternative to Ovsynch/Pre-Synch in which 1.0 mg of estradiol cypionate (ECP) is administered 24 hours after the PGF_{2α} injection of Ovsynch to induce ovulation rather than administering GnRH 48 h after PGF_{2α}. Based on preliminary studies, Heat-Synch results in similar reproductive performance to Pre-Synch but may not be effective for synchronizing anovular cows.
- Insertion of a **CIDR device** between the first GnRH injection and the PGF_{2α} injection of Ovsynch may be an effective strategy for inducing cows that are anovular past the voluntary waiting period to conceive to TAI.

Introduction

A flood of new timed insemination protocols has been introduced to the dairy industry since the introduction of Ovsynch in the mid 1990's. The variety of modifications of the original Ovsynch protocol has lead to much confusion among dairy producers and their reproductive consultants regarding the "best" timed insemination protocol to implement on a dairy. This paper outlines the major timed insemination protocols available for use in lactating dairy cows at the present time and discusses some of the new data in this exciting area of reproductive research. Each of these protocols should be viewed as a reproductive management tool that can be implemented on a dairy farm. Integration of TAI protocols with current and future technologies should allow for development of resynchronization strategies.

Follicular Waves in Cattle

Development of the timed insemination protocols in this review was possible due to basic research data on ovarian function. Once the processes of luteal and follicular function were defined and understood, reproductive physiologists could then precisely control ovarian events and develop practical protocols to manage reproduction in cattle. Discovery of follicular waves in cattle was a major step in this process.

Female reproductive tissues, including ovarian follicles and CL, are some of the fastest growing tissues in the adult female and also are some of the few adult tissues to exhibit periodic and dynamic growth and regression (Reynolds et al., 1992; Luck and Zhao, 1995). For example, antral ovarian follicles can increase or decrease in diameter by more than two millimeters per day. Until recently, little was known of the temporal associations among growing and regressing follicles during an estrous cycle because of the difficulties of studying rapidly growing and regressing tissues *in vitro*. A technologic breakthrough using transrectal ultrasonic imaging was reported in 1984 (Pierson and Ginther, 1984) and has led to clarification of the nature of antral follicular development in cattle (Ginther et al., 1996). Transrectal ultrasonic imaging provides a means for repeated, direct, noninvasive monitoring and measuring of ovarian follicles regardless of their depth within the ovary. Transrectal ultrasonic imaging has revolutionized our understanding of follicular growth for antral follicles ≥ 3 mm in diameter, the smallest follicles that can accurately be resolved and tracked using transrectal ultrasound.

Studies using ultrasound revealed that follicular growth occurs in waves, each wave culminating with formation of a large follicle (Figure 1). A follicular wave begins with emergence of a group or cohort of small antral follicles just before the day of ovulation. During the next several days, one of the follicles in this cohort continues to grow and becomes dominant, thereby suppressing emergence of a new follicular wave. As the

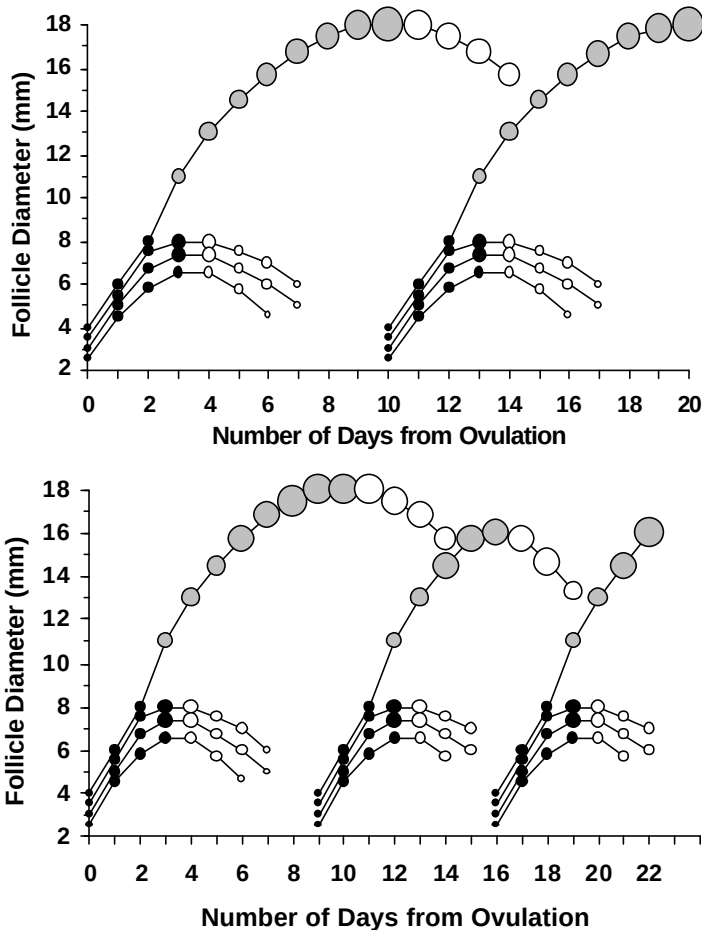


Figure 1. Schematic diagram depicting two-wave (a) and three-wave (b) patterns of follicular growth during the bovine estrous cycle. Growing follicles before selection of the dominant follicle are depicted as black circles, the dominant follicles of each wave are depicted as gray circles, and atretic follicles are depicted as open circles. Refer to text for details.

dominant follicle continues to grow, growth of the remaining follicles in the cohort ceases or slows, and these subordinate follicles eventually undergo atresia. A second wave of growth emerges on approximately Day 10 after ovulation and, for three-wave cycles, an additional wave emerges at Day 16 after ovulation. For both two and three-wave cycles, the ovulatory follicle arises from the final wave. Wave duration and the maximal size attained by the dominant follicle of the first wave are similar for both two- and three-wave cycles (Ginther et al., 1989). Wave duration is shorter and the dominant follicle is smaller for the second wave of a three-wave cycle compared with the first wave (Ginther et al., 1989).

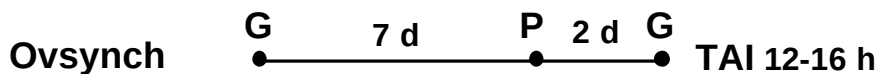
The first reports using ultrasound indicated that the number of follicular waves occurring in cycling heifers varied among animals. Some heifers exhibit two, whereas others exhibit three successive waves of follicular growth during each estrous cycle (Savio et al., 1988; Sirois and Fortune, 1988; Ginther et al., 1989; Taylor and Rajamahendran, 1991). Several factors that influence the number of waves per estrous cycle in dairy cattle include dietary intake (Murphy et al., 1991), age, parity, and lactational status (Lucy et al., 1992). The discovery of follicular waves made it clear that both follicular and luteal function had to be controlled to precisely synchronize the estrous cycle of cattle. In general, primiparous and multiparous lactating dairy cows tend to more frequently exhibit two-wave cycles, whereas nulliparous dairy heifers tend to more frequently exhibit three-wave cycles (Sartori et al., 2000). Thus,

the overall effectiveness of each of the hormonal synchronization systems outlined here will vary depending on the number of follicular waves expressed per cycle. Because, animals exhibiting two waves synchronize better than animals with three or more waves per cycle, these TAI protocols generally give poor results for dairy heifers and good results for high-producing lactating dairy cows. Recent results have shown that lower producing lactating dairy cows managed in grazing-based dairies may respond poorly to Ovsynch, presumably because of a high proportion of cows exhibiting more than two waves per cycle (Cordoba and Fricke, 2001).

Synchronization of Estrus using Prostaglandin $F_{2\alpha}$

Synchronization of estrus behavior has been used to improve reproductive efficiency in cattle. Synchronization protocols using hormones approved for lactating dairy cows have been limited to prostaglandin (PG) $F_{2\alpha}$ (Lucy et al., 1986; Stevenson et al., 1987; Archibald et al., 1992; Stevenson and Pursley, 1994). This hormone is available commercially, and many studies have shown that use of $PGF_{2\alpha}$ can reduce the interval between detected estrous cycles and improve estrus detection efficiency. However, $PGF_{2\alpha}$ does not regress the early corpus luteum (less than 6 days after estrus); therefore, two injections of $PGF_{2\alpha}$, administered fourteen days apart, are required to effectively synchronize estrus in lactating cows. Also, $PGF_{2\alpha}$ does not synchronize anovular cows, which constitute 15 to 30% of all lactating dairy cows in the breeding group (Stevenson and Pursley, 1994; Pursley et al., 2001).

Synchronization of estrus with $PGF_{2\alpha}$ has been successful if cattle are bred at a detected estrus (Lucy et al., 1986; Stevenson et al., 1987; Larson and Ball, 1992), because estrus detection rates increase and management of AI is more efficient compared with daily estrus detection. However, estrus is not precisely synchronized with $PGF_{2\alpha}$ in lactating dairy cows that respond to $PGF_{2\alpha}$ because this treatment only regulates the life span of the corpus luteum and does nothing to synchronize the pattern of follicular waves. Thus, cows with functional corpora lutea will come into heat over a 7-day period after treatment with $PGF_{2\alpha}$ depending on the stage of follicular growth at the time of luteal regression. Furthermore, when cows received a fixed-time AI 72-80 h after a second injection of $PGF_{2\alpha}$, pregnancy rate per AI was about half of that of cows bred at a detected estrus (Lucy et al., 1986; Stevenson et al., 1987; Larson and Ball, 1992).

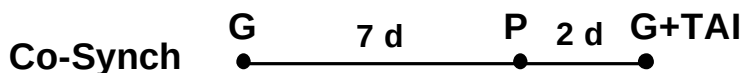


G=GnRH, 50 to 100 mg; P= $PGF_{2\alpha}$, 25 mg; TAI=timed artificial insemination

Reproductive physiologists had long searched to develop a synchronization program that could overcome the problems and limitations associated with visual estrus detection. Such a program was developed at the University of Wisconsin-Madison in 1995 (Pursley

et al., 1995) and is now commonly referred to as Ovsynch. Because Ovsynch synchronizes ovulation rather than estrus, managers no longer need to rely on estrus detection, which is inefficient on most dairy operations, to artificially inseminate their cows. Because ovulation is precisely timed using Ovsynch, lactating dairy cows can receive a TAI while maintaining a conception rate similar to that of cows bred to an estrus. Many studies have shown Ovsynch to be a highly effective and economical strategy for improving reproductive performance in high-producing lactating dairy cows (Burke et al., 1996; Pursley et al., 1997a, b; Britt and Gaska, 1998).

The Ovsynch protocol involves two hormones that are approved for use by the FDA in lactating dairy cows. Administered at a random stage of the estrous cycle, the first injection of GnRH induces ovulation in 65% of cows and causes emergence of a new follicular wave in 100% of cows. The PGF_{2α} injection induces regression of the spontaneous and/or GnRH-induced corpora lutea, and the second GnRH injection synchronizes the time of ovulation of the dominant follicle of the follicular wave that began growing after the first GnRH injection. Ovulation of a dominant follicle in response to the second GnRH injection occurs in 85% of lactating cows receiving this protocol (Fricke et al., 1998), and ovulation occurs within 24 to 32 h after the second GnRH injection in synchronized cows followed by growth of a new follicular wave (Pursley et al., 1995). Using a 50 µg dose (1.0 ml) of Cystorelin for each injection of the Ovsynch protocol results in similar synchronization and conception rates as using a 100 µg dose (2.0 ml) of Cystorelin (Fricke et al., 1998). Although a reduced dose of Cystorelin has been shown to be effective, the labeled dose of PGF_{2α} should be used for all of the protocols described here.



G=GnRH, 50 to 100 mg; P=PGF_{2α}, 25 mg; TAI=timed artificial insemination

The term Co-Synch has been used for a specific version of the original Ovsynch protocol in which cows receive TAI immediately after administration of the second GnRH injection. Use of Co-Synch allows dairy managers to restrain cows for treatment purposes one less time compared to the original Ovsynch protocol. Although this may be advantageous from a management standpoint, optimal conception rates are not achieved using Co-Synch (Pursley et al., 1998). Thus dairy farmers should be aware of data that has assessed conception rates at various times in relation to the second GnRH injection of the Ovsynch protocol shown in Table 1 before making a management decision to implement Co-Synch.

To assess the optimal time of AI in relation to synchronized ovulation, lactating dairy cows (n = 733) from Wisconsin dairy herds with 22,000 to 26,000 pound rolling herd averages were randomly assigned to five groups by stage of lactation and parity (Pursley

et al., 1998). Ovulation was synchronized using Ovsynch, and cows received AI at 0, 8, 16, 24, or 32 hours after the second injection of GnRH. In this study, the 0 h group is equivalent to the Co-Synch protocol. As determined in a preliminary study, all cows ovulate 24 to 32 hours after the second GnRH injection. Injection times were varied so that all cows were inseminated at the same time, and the inseminators were blind to treatment group. Pregnancy status was determined 25 to 35 days after AI for all groups by using transrectal ultrasonography. Conception rate and calving rate was greater ($P<0.05$) for cows in the 0, 8, 16, and 24-hour groups compared with the 32-hour group (Table 1). Pregnancy loss was less ($P<0.05$) for the 0 hour group compared with all other groups, and there was a tendency for greater pregnancy loss in the 32-hour group ($P<0.1$; Table 1). Thus, although no statistical difference in conception rate occurs when breeding from 0 to 24 hours after the second GnRH injection, breeding too late (i.e., at 32 hours) decreases conception rate.

Table 1. Reproductive measures in lactating dairy cows inseminated at various times in relation to ovulation synchronized with an injection of GnRH (Purlsey et al., 1998). In this experiment, the 0 hour group is equivalent to Co-Synch.

Item	Hours from second GnRH to TAI					Total
	0	8	16	24	32	
n	149	148	149	143	143	732
Conception rate ^a (%)	37	41	45	41	32**	39
Pregnancy loss (%)	9**	21	21	21	32	22
Calving rate (%)	31	31	33	29	20*	29

^aQuadratic effect of treatment ($P<0.01$).

*Differs within a row ($P<0.05$).

** Differs within a row ($P<0.10$).

Effect of Day of the Estrous Cycle on Synchronization of Ovulation

One of the advantages of Ovsynch is that it can be initiated at a random stage of the estrous cycle. However, several studies investigated the effect of the stage of the estrous cycle on initiation of Ovsynch, which has lead to a modification of Ovsynch called Pre-Synch. To fully understand how Pre-Synch works to improve upon the original Ovsynch protocol, the data of Vasconcelos et al. (1999) are reviewed next.

To determine the effect of day of the estrous cycle on which synchronization of ovulation was initiated on the efficacy of the synchronization protocol, lactating dairy cows (n=159) with a known estrus date within 22 days of initiation of the first GnRH injection of the protocol were examined by ultrasound on the day of each injection of the protocol, and 24 and 48 h after the second GnRH injection (Vasconcelos et al., 1999). Cows were grouped by the day of the cycle on which synchronization was initiated as follows: Day 1-4 (n=31) Day 5-8 (n=38) Day 9-12 (n=39) Day 13-16 (n= 24) Day 17-22 (n=27). Based on the ultrasound examinations, the percentage of cows ovulating after the first GnRH injection and the second GnRH injection was determined. Cows that ovulated within 48 h of the second GnRH injection were used to determine the synchronization rate.

Table 2. Effect of day of the estrous cycle on the ovulatory response (%) after each GnRH injection of the synchronization protocol (Vasconcelos et al., 1999).

Day of the cycle	n	% of cows ovulating in response to:	
		1 st GnRH injection	2 nd GnRH injection
1-4	31	23	94
5-8	38	95	90
9-12	39	56	87
13-16	24	63	78
17-22	27	74	80

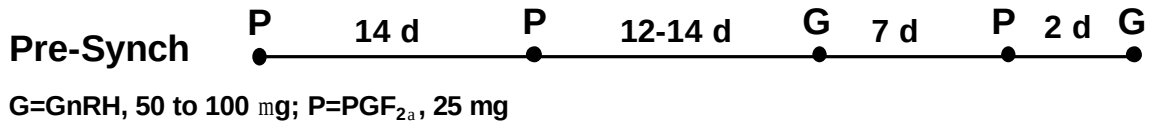
Table 2 shows the effect of the day of the estrous cycle on the percentage of cows ovulating after each injection of the synchronization protocol. Ovulatory response to the first GnRH injection is lowest on days 1 to 4 of the cycle because a dominant follicle capable of ovulating is not present in most cows, whereas the greatest response occurs on day 5 to 8 of the cycle when nearly all cows, regardless of whether they exhibit two or three follicular waves, have an ovulatory follicle. Interestingly, the synchronization rate to the second GnRH injection is greatest when the first GnRH injection is administered on day 1 to 4 of the cycle, when the response to the first GnRH injection is lowest. Thus, cows do not necessarily need to respond to the first GnRH injection to synchronize to the second GnRH injection.

Table 3. Ovulatory responses to the synchronization of ovulation protocol (Vasconcelos et al., 1999).

Ovulation to 1 st GnRH		Ovulation to 2 nd GnRH		
		Before	Synchronized	None by 48 h
YES	100 (63%)	0 (0%)	97 (91%)	8 (8%)
Day	(1-12)	0	58	7
	(13-22)	0	39	1
No	59 (37%)	9 (15%)	47 (80%)	3 (5%)
Day	(1-12)	0	40	3
	(13-22)	9	5	0

Table 3 shows the outcome of cows that either synchronized or failed to synchronize to the second GnRH injection of the protocol. Cows were classified into positive and negative responses to the first GnRH injection of the protocol, and further subdivided into the stage of the estrous cycle (first half, Day 1-12 vs. second half, Day 13-22) at the time they received the first GnRH injection. Of interest in this study are the cows that fail to synchronize to the second GnRH injection of the protocol. Two primary groups of nonsynchronized cows emerge from these data. Nonsynchronized cows that responded to the first GnRH injection were primarily in the first half of the estrous cycle when the protocol was initiated. These cows likely initiate growth of a new follicular wave in response to ovulation of a dominant follicle; however, the follicle grows quickly and loses dominance during the nine-day interval between GnRH injections and fails to ovulate to the second GnRH injection. In contrast, nonsynchronized cows that fail to

ovulate to the first GnRH injection are primarily in the second half of the estrous cycle when they received the first GnRH injection. These cows exhibit estrus during the protocol before the second GnRH injection because the corpus luteum regresses and the cow naturally comes into heat.



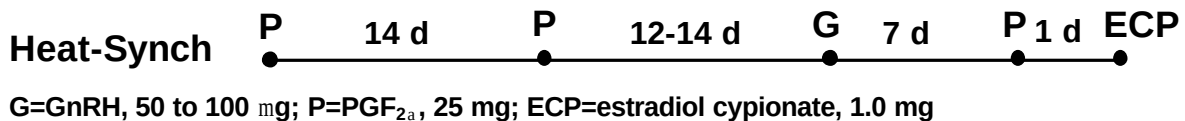
Results from Vasconcelos et al. (1999) using lactating dairy cows, and those of Moreira et al. (2000a) using dairy heifers suggested that initiation of Ovsynch between day 5 to 10 of the estrous cycle may result in improved conception rate over the Original Ovsynch protocol. Hormonal resynchronization of cows to group randomly cycling cows to initiate Ovsynch between day 5 to 10 of the estrous cycle can be accomplished using two injections of PGF_{2α} administered before initiation of the first GnRH injection of Ovsynch.

A presynchronization strategy in which two injections of PGF_{2α} administered 14 d apart preceded initiation of Ovsynch by 12 d has shown to improve conception rate in lactating dairy cows compared to Ovsynch (Moriera et al., 2000c). Lactating dairy cows were randomly assigned to receive Ovsynch (n=262) or Pre-Synch (n=264) for their first postpartum TAI, which was conducted 16 h after the second GnRH injection. The first and second PGF_{2α} injections for Pre-Synch cows were given at 37 and 51 days in milk, respectively, and all cows received a TAI at 73 days in milk. Conception rate increased from 29% for Ovsynch to 43% for Pre-Synch cows. Thus, use of Pre-Synch for programming lactating dairy cows to receive their first postpartum TAI can improve first service conception rate in a dairy herd. Obviously, however, Pre-Synch is not a good resynchronization protocol because of the duration of the protocol and should be used only for cows at their first postpartum AI service.

A common question regarding the original Pre-Synch data from Moriera et al. (2000c) pertains to the importance of the 12-day interval between the second PGF_{2α} injection and the first GnRH injection. If this interval could be extended to 14 rather than 12 days, the first four injections could be scheduled to occur on the same day during successive weeks. This becomes important for compliance on dairy farms that assign groups of cows to initiate the protocol weekly so that injection schedules do not get confused among the groups.

A study is currently being conducted to determine if two injections of PGF_{2α} 14 d apart administered 14 d before initiation of Ovsynch, would change follicular dynamics, ovulation rate, and conception rate in lactating dairy cows. Results from this study are preliminary and differences between treatments are not statistically significant due to

insufficient numbers of cows that have completed each treatment to date. Nonpregnant lactating dairy cows (n=192) at >60 days in milk were randomly assigned to receive either Ovsynch or Pre-Synch. The percentage of cows in which a follicle ovulated after the second GnRH injection was 68 and 82% and conception rates were 41.0 vs. 51.5% for Ovsynch vs. Presynch, respectively. These preliminary data indicate that preceding Ovsynch by 14 d with two injections of PGF administered 14 d apart may improve conception rate similar to that of the original Pre-Synch protocol.



The most recent of the TAI protocols described here arose from studies on the effectiveness of using an estrogen rather than GnRH to induce ovulation to facilitate TAI (Lopes et al., 2000; Jordan et al., 2001; Pancarci et al., 2001). Estradiol cypionate (ECP; Pharmacia Animal Health, Kalamazoo, MI) is the oil-soluble 17β-cyclopentylpropionate ester of alpha estradiol. It provides estradiol-17β, in the form of the cyclopentylpropionate ester, a highly fat-soluble derivative with a prolonged estrogenic effect. Furthermore, ECP is approved for use in lactating dairy cows. Administration of an estrogen in the absence of progesterone and the presence of a follicle with ovulatory capacity causes ovulation by stimulating GnRH release from the hypothalamus, which in turn causes a surge in pituitary LH secretion, the ovulatory stimulus.

There are two primary differences between Pre-Synch and Heat-Synch: 1) 1.0 mg (0.5 ml) of ECP replaces GnRH at the last injection and 2) ECP is administered 24 h after PGF_{2α} compared with 48 h after PGF_{2α} for GnRH. For Heat-Synch cows, TAI occurs 48 h after the ECP injection. Two preliminary field trials have compared Pre-Synch and Heat-Synch for TAI in primiparous and multiparous lactating dairy cows (Jordan et al., 2001; Pancarci et al., 2001). In the first study (Pancarci et al., 2001), cows received either Pre-Synch (n=179) or Heat-Synch (n=192). For primiparous and multiparous cows, conception rate for Pre-Synch was 43.5 ± 6.9% and 30.6 ± 7.2% compared with 50.7 ± 6.3% and 19.4 ± 6.5% for Heat-Synch. Overall, conception rate did not differ between treatments. These results indicate that ECP can be used to induce ovulation for TAI in lactating dairy cows, but that ECP may not be as effective as GnRH for inducing ovulation in anovular cows. In the second study (Jordan et al., 2001), conception rate for cows exhibiting estrus behavior at TAI was 32.8 ± 8.2% (n=28) for Pre-Synch and 40.4 ± 4.1% (n=107) for Heat-Synch, but 26.8 ± 3.8% (n=129) and 6.6 ± 5.7% (n=57), respectively for cows not in estrus at TAI. Based on these results, conception rates at first synchronized insemination will be similar for cows receiving either ECP or GnRH as the ovulatory hormone for TAI.

One advantages of using ECP in a protocol for TAI is its lower cost (\$0.54 per 1.0 ml dose) compared with GnRH. In addition, cows receiving ECP usually exhibit estrus behavior as well as uterine tone at TAI. Heat-Synch can be considered an alternative to Pre-Synch but may not work well in herds with a high percentage of anovular cows past the voluntary waiting period. The authors of these studies have also recommended breeding any cows detected in standing estrus by 24 h after the ECP injection to improve overall response to the protocol. Cows not detected in estrus at 24 h then receive TAI at 48 h after ECP.

Ovsynch + CIDR Device **G** 7 d + CIDR **P** 2 d **G** TAI 12 h

G=GnRH, 50 to 100 mg; P=PGF_{2a}, 25 mg; CIDR=controlled internal drug-releasing device; TAI=timed artificial insemination

Currently, the FDA is conducting the approval process for a controlled intravaginal drug-releasing (CIDR) device for use in dairy and beef heifers and postpartum beef cows. Each CIDR device is produced by coating a nylon spine with silicon-based elastomer containing 1.38 g of progesterone. When inserted into the vagina, CIDR devices deliver a defined amount of progesterone that inhibits estrus behavior in cattle (Macmillan and Peterson, 1993). Advantages of using IPI devices include ease of insertion and withdrawal (compared with ear implants) and high retention rates (Macmillan et al., 1988, 1991). The CIDR device is currently approved for use in Canada, Mexico, New Zealand, and Australia. Although there are many potential uses for the CIDR device, we have conducted one study using the CIDR in conjunction with Ovsynch in lactating dairy cows (Pursley et al., 2001). It is important to note, however, that the initial approval of the CIDR in the U.S. will not include lactating dairy cows.

Our objective was to determine if increased progesterone (P₄) before induced luteolysis would enhance fertility in lactating dairy cows. To increase P₄ we tested the effect of an intravaginal progesterone device (CIDR) inserted at the first injection of GnRH of the Ovsynch protocol. The CIDR was removed 2 h prior to PGF_{2a} induced luteolysis. Lactating dairy cows (n=633) from six Midwest herds were assigned randomly within parity and stage of lactation to receive Ovsynch or Ovsynch + CIDR at a random stage of an estrous cycle. Blood was sampled to quantify P₄ 10 d before first GnRH, at first GnRH, at removal of CIDR, at PGF_{2a}, and 36 h post-PGF_{2a} to determine cycling status at time of first GnRH, status at time of PGF (high or low P₄), and whether CL regressed. Synchronization rate was defined as percentage of cows that experienced a decrease in P₄ from CIDR removal to 36 h post-PGF_{2a} and had a follicle > 9 mm that disappeared within 48 h after second GnRH. Pregnancy diagnosis at 28 and 56 d following AI was determined by ultrasound.

Tables 4 and 5 show the results from this study. Overall conception rate did not differ between Ovsynch and Ovsynch + CIDR on d 28 post-AI, primarily due to a location by treatment interaction. Non-cycling cows that received Ovsynch + CIDR had higher conception rates than non-cycling cows that received Ovsynch on d 28 post-AI. However, pregnancy loss was greater for anovular cows that conceived compared with cycling cows that conceived. In summary, a CIDR inserted during the Ovsynch protocol increased fertility in non-cycling cows, but not cycling cows. Incorporation of a CIDR device with the Ovsynch protocol may be the best strategy for dealing with lactating dairy cows that are anovular at the end of the voluntary waiting period. This protocol cannot be used on farms until the FDA approves use of the CIDR device in lactating dairy cows.

Table 4. Effect of CIDR during Ovsynch on conception rate (%) at 28 d post TAI.

Status	Ovsynch		Ovsynch+CIDR		Total	
	%	n	%	n	%	n
Cyclic	43.5	225	49.1	226	46.3	451
Anovular	34.7	95	55.2*	87	44.5	182
Total	40.9	320	50.8	313	45.8	633

*Treatment difference ($P<0.025$).

Table 5. Effect of CIDR during Ovsynch on early embryonic loss (%) from 28 to 56 d post TAI.

Status	Ovsynch		Ovsynch+CIDR		Total	
	%	n	%	n	%	n
Cyclic	18.6	98	11.7	111	14.8*	209
Anovular	30.3	33	33.3	48	32.1	81
Total	21.4	131	18.2	159	19.7	290

*Status difference ($P<0.001$).

Resynchronization Strategies

New technologies to identify nonpregnant dairy cows early post AI may play a key role in a reproductive management strategy for commercial dairy farms. When using ultrasound for early pregnancy diagnosis, emphasis must be given to identifying nonpregnant rather than pregnant cows. Coupling a nonpregnancy diagnosis with a management decision to quickly reinitiate AI service improves reproductive efficiency and pregnancy rate by decreasing the interval between AI services, thereby increasing AI service rate. Because AI conception rates of high producing lactating dairy cows are reported to be 40% or less (Fricke et al., 1998; Pursley et al., 1997a,b), 60% or more of cows will fail to conceive to an AI service and, therefore, will require a resynchronization strategy for aggressively initiating a subsequent AI service. Ovsynch, a protocol for synchronizing ovulation in lactating dairy cows, uses injections of GnRH and PGF_{2α} (Pursley et al., 1995, 1997a) and is an effective method for hormonally programming cows to receive a timed AI service. Hormonal resynchronization systems that program nonpregnant cows to receive a subsequent AI service need to be developed and assessed to aggressively manage reproduction in lactating dairy cows. Research into the efficacy

of protocols that combine timed AI with ultrasonography for aggressive reproductive management of dairy cattle is underway (Fricke, 2001).

Conclusion

Basic research using transrectal ultrasonography has elucidated the nature of ovarian follicular development in cattle. Once understood, a protocol (Ovsynch) that precisely synchronizes follicular development and ovulation in lactating dairy cows was developed that allows for a timed artificial insemination that results in conception rates similar to those of cows artificially inseminated to a standing estrus for lactating dairy cows managed in confinement-based dairies in the United States. Modifications of Ovsynch such as Pre-Synch can further enhance conception rate to TAI, whereas Co-Synch may make management of cows easier but at a cost to conception rate. Heat-Synch is an alternative to Pre-Synch, but may not work well in anovular cows. Future and ongoing research is focused on further improving synchronization and conception rates to timed artificial insemination using modifications of this protocol, and on understanding the underlying physiology that determines whether cows synchronize to the protocol.

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