Assessment of an Activity Monitoring System for Detection of Estrus and Timing of Artificial Insemination in Lactating Dairy Cows

Introduction

Despite the widespread adoption of hormonal synchronization protocols that allow for timed artificial insemination (TAI), detection of behavioral estrus continues to play an important role in the overall reproductive management program on most dairies in the United States (Caraviello et al., 2006; Miller et al., 2007).

Several challenges for estrous detection on farms include attenuation of the duration of estrous behavior associated with increased milk production near the time of estrus resulting in shorter periods of time in which to visually detect estrous behavior (Lopez et al., 2004), low number of cows expressing standing estrus (Lyimo et al., 2000; Roelofs et al., 2005; Palmer et al., 2010), silent ovulations (Thatcher and Wilcox, 1973; Palmer et al., 2010; Ranasinghe et al., 2010), and reduced expression of estrous behavior due to confinement (Palmer et al., 2010).

Whatever the cause, the low efficiency of estrous detection not only increases time from calving to first artificial insemination (AI) but also increases the average interval between AI services (Stevenson and Call, 1983), thereby limiting the rate at which cows become pregnant.

Because of the impact of AI service rate on reproductive performance and the problems associated with visual estrous detection on farms, new electronic systems that incorporate activity monitoring as a means to associate increased physical activity with estrous behavior in cattle (Holman et al., 2011; Jónsson et al., 2011) have been developed and marketed to the dairy industry. Whereas a large body of literature exists on the accuracy and efficacy of using various technologies to predict ovulation and timing of AI in relation to ovulation in lactating dairy cows, few studies have investigated activity monitors for such purposes.

Experiment

To assess the use of an activity monitoring system for reproductive management, lactating Holstein cows from a commercial dairy farm located in southwestern Wisconsin milking approximately 1,000 cows were used in a field trial, which was performed from August 2010 to June 2011 (Valenza et al., 2012). At 14 d after calving, all cows were fitted with an activity monitoring tag (Heatime®, SCR Engineers Ltd., Netanya, Israel) attached to a neck collar and an electronic identification tag. After each milking, data collected by the activity monitoring system were read by a transceiver unit placed in an archway at the milking parlor exit and then transferred to the activity monitoring system herd management software (Data Flow™; Micro Dairy Logic, Amarillo, TX) installed on the on-farm computer.

The activity monitoring system continuously monitored individual cow activity and recorded average activity for 2 h time periods. The raw activity of individual cows was plotted as a bar graph where each bar represented a 2 h block of time. The onset of activity was defined as the time at which the first bar of raw activity of an estrous event was identified. Duration of activity was defined as the time interval between the beginning and end of activity for an estrous event. Twice daily (a.m. and p.m.), a list of cows determined by the activity monitoring system to be eligible for insemination was generated, and cows appearing on this list were inseminated. Thus, inseminations were conducted twice daily (a.m. and p.m.) by two herd personnel with each cow receiving a single insemination based on activity.

Each week, cohorts of 10 to 15 cows from 46 to 52 DIM were evaluated by transrectal ultrasonography to determine uterine health and record ovarian structures. Cows without signs of uterine disease and at least one follicle ≥ 10 mm in diameter received an intramuscular (i.m.) injection of GnRH followed by an i.m. injection of...
PGF<sub>2α</sub> 7 d later to synchronize estrus (Figure 1). Transrectal ultrasonography was performed at the time of the PGF<sub>2α</sub> injection for subsequent determination of ovulatory response to GnRH treatment. A total of 112 cows were enrolled, but only 89 cows that were considered properly synchronized were included in the analyses. Diameter of ovarian structures was estimated and recorded using on-screen background gridlines comprising squares with 10 mm sides in the portable scanner. Ovulation was defined as the presence of a follicle ≥ 10 mm at the initial ultrasound examination at the time of the GnRH injection and the presence of a new corpus luteum in the same location at the subsequent ultrasound examination at the time of the PGF<sub>2α</sub> injection. Thereafter, beginning 48 h after the PGF<sub>2α</sub> injection, ovarian ultrasonography was performed every 8 h until ovulation occurred, or until 96 h, whichever occurred first. Cows failing to ovulate within 96 h of the PGF<sub>2α</sub> injection were re-examined 3 d later (i.e., 7 d after the PGF<sub>2α</sub> injection) to determine whether ovulation had occurred.

Figure 1. Schematic diagram of activities for Experiment 1. Cows (n = 112) from 46 to 52 d postpartum received a hormonal protocol to synchronize estrus using i.m. injections of GnRH (100 µg) and PGF<sub>2α</sub> (25 mg). Transrectal ultrasonography (US) was used to assess ovarian structures during the protocol and time of ovulation after induction of luteolysis, and blood samples (B) were collected to assess serum progesterone. After eliminating 23 cows that failed to synchronize to the protocol, 89 cows were included in the analysis (from Valenza et al., 2012).

Results

The percentage of cows with estrous events detected by the activity monitoring system and the distribution of cows by occurrence of estrus and ovulation are presented in Table 1. Throughout the study period, 78% of cows ovulated within 7 d after induction of luteolysis. Of the cows that ovulated, 59% ovulated within 96 h, whereas 41% ovulated from 96 to 168 h (4 to 7 d) after induction of luteolysis. Overall, 71% of cows were detected in estrus by the activity monitoring system, and 95% of cows showing estrus ovulated, whereas 5% did not ovulate within 7 d of induction of luteolysis. Of the cows not detected in estrus by the activity monitoring system, 35% ovulated, whereas 65% did not ovulate within 7 d of induction of luteolysis.

Table 1. Percentage of cows determined to be in estrus, and distribution of cows by estrous activity and ovulation after induction of luteolysis based on use of an activity monitoring system

<table>
<thead>
<tr>
<th>Activity and ovulation responses of cows after induction of luteolysis</th>
<th>% (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cows with estrous activity</td>
<td>71 (63/89)</td>
</tr>
<tr>
<td>Cows that ovulated</td>
<td>95 (60/63)</td>
</tr>
<tr>
<td>Cows with no ovulation</td>
<td>5 (3/63)</td>
</tr>
<tr>
<td>Cows with no estrous activity</td>
<td>29 (26/89)</td>
</tr>
<tr>
<td>Cows that ovulated</td>
<td>35 (9/26)</td>
</tr>
<tr>
<td>Cows with no ovulation</td>
<td>65 (17/26)</td>
</tr>
</tbody>
</table>

1 Heatime<sup>®</sup>, SCR Engineers Ltd., Netanya, Israel.

The duration of estrous activity for cows detected in estrus by the activity monitoring system (16.1 ± 4.7 h, range = 4.0 to 28.0; Figure 2) was not affected (P = 0.74) by parity (16.4 vs. 17.2 h for primiparous and multiparous,
respectively) or milk production near the time of estrus ($P = 0.51$). The duration of estrus observed in this experiment is comparable to the mean duration (13.4 h) reported for cows monitored for estrus by visual observation of both primary (standing to be mounted) and multiple secondary signs of estrous behavior (Roelofs et al., 2004). Conversely, duration of estrus activity observed in the present experiment is considerably longer than the mean duration of estrus based on the interval between the first and last standing event of estrus detected using an electronic pressure-sensing system (Dransfield et al., 1998; Xu et al., 1998). Discrepancies between the duration of estrus based on activity or visual observation with that recorded based on standing events are possibly due to the uncoupling of expression of secondary signs of estrous behavior and standing estrus. Indeed, Sveberg et al. (2011) reported that secondary signs of estrous behavior, which can certainly be detected by visual observation of increased activity, increased significantly within 1 to 3 h before the initiation of standing estrus in lactating dairy cows.

**Figure 2.** Distribution of cows based on duration of activity associated with estrus for cows detected in estrus by an activity monitoring system (Heatime®) within 7 d after synchronization of estrus (from Valenza et al., 2012).

We did not expect that ~30% of cows would fail to show estrus within 7 d after the PGF$_2$α injection because a follicle >10 mm was present in all cows at the time of the PGF$_2$α injection, and all cows included in the analysis underwent luteal regression within 48 h after PGF$_2$α treatment. In another study in which cows received two sequential PGF$_2$α injections at 35 and 49 DIM, only 67.9% of cows determined to be cycling by 49 DIM were detected in estrus and inseminated after the second PGF$_2$α injection, leading the authors to conclude that issues other than cyclicity status affected efficiency and accuracy of estrous detection (Chebel and Santos, 2010). The percentage of cows that failed to ovulate within the group of cows not detected in estrus was 65% for the activity monitoring system, suggesting that estrus did not occur in these cows. The remaining 35% of ovulations in cows not detected in estrus may have been silent ovulations (ovulation without estrus), a phenomenon described in lactating dairy cows especially during the early postpartum period (Thatcher and Wilcox, 1973; Palmer et al., 2010; Ranasinghe et al., 2010). In addition, 5% of cows detected in estrus failed to ovulate within 7 d after induction of luteolysis. In another study, the overall rate of ovulation failure in lactating dairy cows that showed estrus behavior was 6.5% and was greater during the warm season than during the cool season (López-Gatius et al., 2005). This rate of ovulation failure represents a small percentage of the population of cows in this experiment and could occur due to failure in the mechanism triggering ovulation (i.e., no luteinizing hormone (LH) surge or insufficient LH secretion) or a lack of response by the dominant follicle to the LH surge.

**Figure 3.** Percentage distribution of cows (n = 38; only cows that ovulated and were inseminated were included) based on the interval from AI to ovulation. Artificial insemination was conducted twice daily based on detected estrus defined by the activity monitoring system (Heatime). Ovulation was determined using transrectal ultrasonography conducted every 8 h from 48 to 96 h after induction of luteolysis. Estrus was synchronized using an i.m. injection of GnRH (100 µg) followed 7 d later by PGF$_2$α (25 mg) to induce luteolysis (from Valenza et al., 2012).

Due to the short lifespan of the oocyte in cattle (Hunter, 2003), the interval from AI to ovulation is critical for optimizing fertility in lactating dairy cows inseminated based on detected estrus. In the present study, the mean interval from AI to ovulation was 7.9 h (Figure 3). This mean interval may seem appropriate because it allows for the 6 to 8 h required for the sustained phase of sperm...
transport to the site of fertilization and sperm capacitation (Hunter and Wilmut, 1983; Wilmut and Hunter, 1984; Hawk, 1987); however, the degree of variation in the AI-to-ovulation interval (Figure 3) is a major concern. Overall, 21% of cows received AI between 0 to 12 h after ovulation, a timing associated with low fertilization rates and embryo quality in lactating dairy cows (Roelofs et al., 2006) possibly due to aging of the oocyte during the period required for sperm transport and capacitation. By contrast, only 1 cow was inseminated more than 24 h before ovulation, a period that results in high fertilization rates but low embryo quality possibly due to aging of the spermatozoa (Roelofs et al., 2006). Based on these data, it may be helpful to either reduce the variation in the AI-to-ovulation interval so that more cows are inseminated at the optimal time in relation to ovulation, or alternatively, to inseminate cows a few hours earlier based on the time of AI relative to the activity monitor threshold to reduce the probability of inseminating cows after or around the time of ovulation when detected in estrus using the activity monitoring system.

Conclusion

A practical implication of these data is that only two-thirds of the cows that were considered properly synchronized would have been inseminated based on the activity monitoring system and would go on to ovulate after AI. The remaining cows either would not be inseminated because they were not detected in estrus or would not have a chance to conceive to AI because they would fail to ovulate after estrus. These data underscore the importance of implementing a comprehensive reproductive management program for identification and treatment of cows that would otherwise not be inseminated and to identify those cows failing to ovulate when cycling spontaneously. Based on data from the present experiment using this activity monitoring system, the mean time of AI in relation to ovulation was acceptable for most of the cows detected in estrus; however, variability in the duration of estrus and timing of AI in relation to ovulation could lead to poor fertility in some cows. It should be noted that this experiment was conducted on 89 cows from one dairy herd, and results should not be inferred to other activity monitoring systems due to potential differences among these technologies.

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References


