Effect of Lying Behavior on Uterine Blood Flow in Cows During the Third Trimester of Gestation

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ABSTRACT

Seven Holstein cows (BW = 639.4 ± 28.8 kg, age = 62.6 ± 6.9 mo, parity = 3.1 ± 0.4 yr) (mean $\pm$ SE) were used to measure uterine blood flow using a transit time ultrasonic flow meter. Ultrasonic flow probes were implanted (d 218 ± 4 of gestation) around both uterine arteries ($n = 3$) or the gravid uterine artery ($n = 4$) to measure variations in uterine blood flow through this vessel in response to postural change (standing and lying). Implantation of the ultrasonic blood flow probe was successful in all 7 cows. Uterine blood flow was measured for 22.9, 23.1, and 21.4 h/d on d 226, 248, and 269 of gestation, respectively. Cows exhibited normal durations of gestation (272.8 ± 1.6 d), gave birth to normal healthy calves (birth weight = 41.5 ± 3.0 kg), and did not retain their placenta. Uterine blood flow to the gravid horn during lying was greater than during standing on d 226 (standing vs. lying, 8.04 vs. 8.79 L/min, respectively), d 248 (9.87 vs. 11.06 L/min), and d 269 (8.15 vs. 9.74 L/min) of gestation. Cows spent nearly 50% of their time lying during our observations at all gestational ages. Greater blood supply to the gravid uterus was observed during lying than during standing in this study.

(**Key words:** uterine blood flow, lying, Holstein cow)

Abbreviation key: UBF = uterine blood flow.

INTRODUCTION

Dairy cattle spend approximately 8 to 16 h/d lying down (Dechamps et al., 1989; Haley et al., 2001). Cow comfort may logically be measured in terms of lying behavior, stall usage, and rest time. Haley et al. (2000) used a simple comparison between a space judged to be high in comfort (a large box stall with mattresses) and a stall that represented a low-comfort situation

(a tie stall with concrete flooring). Lying times were 4 h longer, and cows were more willing to stand up and change positions, in the high-comfort stall. Cows also spent more time standing idle in the low-comfort stalls. This study indicates that when a cow is uncomfortable, she is willing to stand for longer periods of time (Tucker and Weary, 2001). Therefore, to improve welfare, comfort, and productivity, appropriate facilities and housing (e.g., stall size, design, bed surface) should facilitate increased lying time.

Nutrient uptake by the gravid uterus in lactating cows and sows is mainly dependent on the rate of uterine blood flow (UBF; Ferrell and Ford, 1980; Ford et al., 1984; Pere and Etienne, 2000; Wallace et al., 2002). Therefore, we supposed that increased blood flow to the gravid uterus would improve fetal welfare and comfort. For lactating animals, blood flow to the mammary gland is increased during lying (Metcalf et al., 1992; Rulquin and Caudal, 1992; Renaudeau et al., 2002). However, little information exists concerning the effect of lying behavior on UBF in pregnant cows.

In a previous study (Nishida et al., 2001), we established the surgical method to measure arterial blood flow to the gravid uterine horn in cows by using transit time ultrasonic flow probes. Bollwein et al. (2002) used transrectal Doppler ultrasound for noninvasive investigation of UBF in 3 cows during pregnancy. However, they put transducers in the rectum to measure UBF during short periods (30 min for each cow), which may not be feasible when cows are lying down. Because of our surgical procedure, placement of the implanted flow probe around the middle uterine artery allows chronic measurement of blood flow during standing and lying for >24 h without stress.

The objective of the present study was to measure chronic differences in blood flow to the gravid and non-gravid uterine horns between standing and lying postures in Holstein cows during the third trimester of gestation.

MATERIALS AND METHODS

Feeding

Seven multiparous, pregnant, dry Holstein cows (Table 1) were used in the experiment. They were fed

Received February 10, 2004.

Accepted April 16, 2004.

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Table 1. Maternal age, parity, BW, gestation length, and birth weight of calves (n = 7).

Age, mo	Parity	BW, ¹ kg	BW, ² kg	Gestation length, d	Birth weight of calves, kg
Mean ± SE					
62.6 ± 6.9	3.1 ± 0.4	639.4 ± 28.8	661.6 ± 26.1	272.8 ± 1.6	41.5 ± 3.0

¹Maternal BW measured at the beginning of the experiment.²Maternal BW measured before parturition.

a ration consisting of 70% timothy hay, 20% flaked corn, and 10% soybean meal on a DM basis during the dry period. To meet the dry cow requirements according to the Japanese Feeding Standard (Agriculture, Forestry and Fisheries Research Council Secretariat, 1994), cows were fed this ration twice daily at 0900 and 1630 h. Water was supplied, and mineral blocks (Koen-S, Nippon Zenyaku Kogyo, Co., Ltd., Fukushima, Japan) were provided ad libitum.

Surgical Procedures

Surgery was conducted on d 218.1 ± 4.1 (mean ± SE) of gestation according to a protocol approved by the Guide for the Care and Use of Experimental Animals (National Institute of Livestock and Grassland Science, Animal Care Committee) and based on the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (1988). Surgical procedures were performed according to our earlier report (Nishida et al., 2001). All materials used for surgery were sterile. Cows underwent feed withdrawal for 48 h, and water was removed 24 h before surgery. Cows were sedated with 60 mg xylazine (Rompun; Bayer Co., Ltd., Germany) by i.m. injection during surgery. The left flank region of each cow was shaved, and underlying skin was disinfected. Multiple s.c. infiltration anesthesia or segmental dorsolumbar epidural anesthesia was administered by using procaine hydrochloride solution (Mitaka Pharmaceutical Co., Ltd., Tokyo, Japan) or bupivacain hydrochloride solution (Marcain; Fujisawa Pharmaceutical Co., Ltd., Osaka, Japan).

Laparotomy was conducted at the left flank of the standing cows, and the middle uterine artery in broad ligament was confirmed by palpation through the incision. A transit time ultrasonic flow probe ("S" series, diameter 12 or 14 mm; Transonic Systems Inc., NY), which had been calibrated at the factory, was fitted around the uterine artery of each cow. Three of 7 cows were fitted on both of the uterine arteries, and the other 4 cows were fitted on only the gravid uterine artery. The uterine artery was covered with the bracket of flow probe without pulling the blood vessel out from the membrane. During abdominal closure,

the flowmeter cable was tunneled s.c. and exteriorized through a small incision in the lumbar fossa. It was then sutured around the skin opening.

Antibiotics were administered i.m. to the cow (1 million U of procaine penicillin G Meiji in aqueous suspension; Meiji Seika Kaisha, Co., Ltd., Tokyo, Japan) immediately after surgery and during 3 d thereafter. Throughout the surgical recovery period (d 218 to 226 of gestation), blood flow probes were monitored daily.

Measurement of Blood Flow

Uterine blood flow was measured at 10-s intervals by using an ultrasonic flow meter (T106, Transonic Systems Inc.) for approximately 22.9, 23.1, and 21.4 h/d on d 226, 248, and 269 of gestation, respectively. Average UBF throughout the monitoring period was calculated from the instantaneous blood flows and recorded by the computer.

Behavioral Observations

All pregnant cows were housed in stalls with rubber chip mattress floors. Behavior of cows was recorded by a digital camera (QV-8000SX; Casio Computer Co., Ltd. Tokyo, Japan) using the interval recording function set at 5-min intervals for approximately 23 h/d. The camera was mounted as conveniently as possible to view cow movements within stalls. Cows were maintained in constant light, and room temperature was 20°C.

Statistics Analyses

Data were analyzed by ANOVA (procedure GLM, SAS Inst., Cary, NC). Dependent variables were UBF, standing, and lying time. Independent variables (posture and gestation period) were analyzed by using the following model:

$$Y_{ij} = \mu + P_i + G_j + PG_{ij} + E_{ij}$$

where

Y_{ij} = dependent variable;

μ = overall mean;

P_i = effect of posture, where $i = 1$ to 2 (standing vs. lying);

G_j = effect of gestation period j , where $j = 1$ to 3 (d 226, 248, and 269 of gestation);

PG_{ij} = posture $\times$ gestation period interaction; and

E_{ij} = residual error.

A single analysis was conducted. Results are expressed as least square means.

RESULTS AND DISCUSSION

Surgeries were completed within 2 h under anesthesia with no problems. Recovery of the cows after surgery was rapid, and cows generally stood, ate, and drank just after surgery. All cows exhibited normal durations of gestation, gave birth to a normal healthy calf (NRC, 2001; Table 1), and did not retain their placenta.

Lying Behavior and UBF

Mean gravid and nongravid UBF during standing and lying positions during 3 different gestational periods are shown in Figure 1. Uterine blood flow to the gravid horns was greater ($P < 0.05$) during lying positions than standing at all gestational ages. The UBF to nongravid horns during lying tended ($P < 0.10$) to be greater than those during standing only on d 269 of gestation. Dunlop et al. (1994) reported that UBF did not change significantly because of maternal positioning in 7 conscious pregnant cows at 45 d before term. Their observations were conducted during 15 to 30 min while cows were restrained with ropes in dorsal recumbency, resulting in more acute and possibly stressful conditions compared with our experimental approach. Perhaps these varying experimental conditions partly explain why their results disagreed with ours.

Lying induced a 24% increase in blood flow in the left common external pudic artery and a 7% decrease in heart rate in 2 Holstein cows (Rulquin and Caudal, 1992). A 28% increase in blood flow occurred through the right external pudic artery when cows were lying down (Metcalf et al., 1992). Renaudeau et al. (2002) measured blood flow through the mammary gland using transit time ultrasonic device in 3 multiparous sows. Pudic artery mammary blood flow was greater when sows were lying than when they were standing (lying vs. standing, 939 vs. 885 mL/min, respectively). Similarly, we observed a significant increase in UBF during lying compared with standing in our study. It is supposed that maintaining the standing position,

Figure 1. Uterine blood flow in the (a) gravid and (b) nongravid horns during standing (□) or lying (■) positions on d 226, 248, and 267 of gestation. Data are means $\pm$ SE during 23 h for 4 (d 226) or 7 (d 248 and 267) pregnant Holstein cows. Numbers above each bar are the mean uterine blood flows (L/min). ** $P < 0.01$, * $P < 0.05$, and † $P < 0.10$ illustrate differences between the 2 postures within day of gestation.

which could be considered very mild and chronic exercise, might increase blood supply to the legs and reduce UBF relative to standing. Uterine blood flow decreased by 36% (Chandler and Bell, 1981) and 18% (Chandler et al., 1985) as a result of moderate exercise. Lotgering et al. (1983) reported that UBF in sheep decreased during maternal exercise, which returned to control values within 10 min of recovery. In these studies, exercise caused UBF to decrease with increasing external workload, which further supports our hypothesis.

Lying Time

Cows spent almost 50% of their time lying during our observations at all gestational times (Table 2).

Table 2. Behavioral observations of pregnant Holstein cows during the third trimester of gestation.

Day of gestation	Behavior (% of observation) ¹			
	Standing	Lying	SEM	P
226 (4) ²	48.0	52.0	7.6	0.996
248 (7)	52.1	47.9	6.3	0.999
269 (7)	52.2	47.8	5.0	0.998

¹Standing and lying percentages total 100%.

²Number in parentheses represents number of cows observed on each day of gestation.

Mean lying times on d 226, 248, and 267 of gestation were 11.8 ± 1.7 h (mean $\pm$ SE, total observation, 22.9 h/d), 11.0 ± 1.5 h (total observation, 23.1 h/d), and 10.4 ± 1.1 h (total observation, 21.4 h/d), respectively. Cows spend nearly one-half of their day lying down, so providing a well-designed space for this behavior is important. A reduction in the time that cows spend lying can lead to physiological changes associated with stress and can have a negative impact on health. When cows were housed on a mattress flooring instead of concrete, total lying time increased by 1.8 h/d (mattress vs. concrete, 51.0% vs. 43.4% time per d, respectively; Haley et al., 2001). Opportunity to lie down freely is often cited as a basic requirement of cows (Munksgaard and Simonsen, 1996; Albright and Arave, 1997). Preventing cows from lying down may be detrimental because the tendency to lie down increases significantly after only a few hours of deprivation (Metz, 1985). Dechamps et al. (1989) reported that the mean lying time (11.6 h/d) did not differ between pregnant and lactating cows, nor did it differ between cows in American- vs. European-type tie-stalls. Percentages of time cows spent lying in our study (nearly 50% of each day) were similar to those reported by Dechamps et al. (1989).

CONCLUSIONS

Cows need to spend a considerable time lying down to decrease maintenance energy requirements for maximum feed efficiency, promote effective rumination, and promote optimum health by preventing lameness. Lying time has been used by dairy researchers to evaluate cow comfort in free stall barns. We observed a significant increase in UBF for cows during the third trimester of gestation while in the lying position. Greater blood supply to the gravid uterus may benefit the growing fetus markedly during late gestation by providing adequate delivery of oxygen and nutrients.

ACKNOWLEDGMENTS

The authors thank the animal caretakers at our institute, especially N. Watanabe, H. Ezure, K. Sato, and C. Nagasawa for helping during the experimental period and the laboratory of ruminant metabolism for the loan of an ultrasonic flow meter. This investigation was supported by a grant from the Clone Project received from Agriculture, Forestry, and Fisheries Research Council funds.

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