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Investigations of mammary and uterine blood flow in relation to milk yield, postpartum disease, and pregnancy result in dairy cows

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ABSTRACT

The objective was to determine the blood flow variables in the uterine arteries and the pudendoepigastric trunks, which supply the mammary gland, and relate these variables to the occurrence of uterine disease, milk yield, and pregnancy result. To achieve this, 119 multiparous German Holstein cows were examined using color Doppler sonography once during the dry period and on Days 7, 14, 28, 42, 56, 66, 76, 86, and 96 postpartum (pp). Cows with retained fetal membranes or metritis had a higher blood flow volume and time-averaged maximum velocity and a lower pulsatility index in the uterine arteries on Days 7, 14 and 28 pp ($P < 0.05$). Milk yield was correlated with blood flow volume in the pudendoepigastric trunks on examination Days 7 to 96 pp with the exception of Day 76 ($P < 0.05$), and with time-averaged maximum velocity on Days 7 and 14 pp ($P < 0.05$). The pulsatility index was greater in the left pudendoepigastric trunk on examination Days 7 to 76 pp than in the right pudendoepigastric trunk ($P < 0.05$). Milk yield did not affect pregnancy result and was not related to uterine perfusion. Increased uterine perfusion in cows with retained fetal membrane and metritis may be due to increased uterine size attributable to delayed involution. High mammary perfusion in high-yielding cows is due to an increased demand for nutrients and oxygen. Color Doppler sonography is a useful method for the investigation of the effect of uterine disease on uterine blood flow and of the effect of milk yield on mammary perfusion.

1. Introduction

Milk yield of dairy cows has increased continuously during the past few decades, whereas fertility parameters such as conception rate have declined [1–5]. Dairy cow fertility is affected by various inflammatory diseases [6,7]. Retained fetal membranes (RFM), metritis, and cystic ovarian disease have a negative impact on conception rate [8]. Cows with acute mastitis in the early postpartum (pp) period had a later onset of ovarian cyclicity (39 ± 2 vs. 32 ± 1 days), and the interval between calving and the first overt estrus was longer compared with healthy cows (84 ± 2 vs. 91 ± 3 days). Acute mastitis induced luteolysis in the luteal phase and delayed ovulation in the follicular phase [9]. Milk yield in the first 60 days had no effect on conception rate, whereas dystocia, RFM, and metritis were associated with lower production [8].

Color Doppler sonography has been used to investigate uterine perfusion in healthy and sick dairy cows. Uterine blood flow volume (BFV) decreased exponentially from 4312 mL/min 1 day pp to 230 mL/min 28 days pp with the most pronounced decrease occurring in the first week. The BFV of the uterine artery of the previously gravid horn decreased by about 50% in the first day pp, whereas it

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remained unchanged between Days 28 and 86 pp [10]. Blood flow can also be determined semiquantitatively using the pulsatility index (PI), which describes resistance to blood flow distal to the point of measurement. A low PI indicates low resistance to blood flow in the peripheral tissue [11]. The PI of the uterine arteries of cows increased from an average of 1.54 on Day 1 to 5.56 on Day 28 pp, after which time it decreased in a linear fashion to 3.13 on Day 86 pp [10].

Color Doppler sonography of the pudendoepigastric trunk also has been used for noninvasive evaluation of the mammary blood flow during lactation in goats and cows [12,13]. The systolic and diastolic blood flow velocity in the external pudendal artery was determined on Days 40, 100, and 210 of lactation and on Day 290 pp in the dry period; blood flow velocity continuously decreased to the lowest value on Day 290 pp [14]. During the first 84 days pp, daily milk yield and BFV in the pudendoepigastric trunks were moderately correlated [13]. The BFV in the external pudendal arteries, respectively, the pudendoepigastric trunk, was similar before and after milking [14,15], but in an earlier study, it increased during milking [16].

The aim of this study was to investigate changes in uterine and mammary perfusion in dairy cows in relation to uterine disease, milk yield, and pregnancy result.

2. Materials and methods

2.1. Animals

The study was conducted from September 2013 to August 2014 and involved 144 German Holstein cows from a 400-cow dairy herd in Lower Saxony, Germany. Twenty-five cows were excluded from the study because of dystocia, twinning, displaced abomasum, lameness, or toxic mastitis, which left 119 cows for analysis. Of these, 56 (47%) were in second, 22 (18%) in third, and 41 (35%) greater than third lactation, respectively. Dry cows were housed in a free stall with cubicles and straw-manure bedding. In the past 2 weeks of gestation, cows were fed the same ration as the high-producing cows, which was on the basis of 30 kg of milk production. The ration contained grass and corn silage, alfalfa hay, potato pulp, ensilaged brewers grains, bakery meal, a mixture of grain, and minerals. Groups of four cows were kept in straw-bedded calving pens, in which they remained after calving for up to 3 days. They were then moved to the group of high-producing cows in the free stall barn. Concentrate was fed individually at transponder stations, and the daily amount was increased gradually to 7 kg on Day 24. Thereafter, the amount was adjusted to production and the cows received one extra kg for every 2 kg of milk exceeding 30 kg.

Cows were milked twice daily between 5 AM and 8 AM and between 4 PM and 7 PM in a rotatory herringbone parlor milking system HBR from DeLaval GmbH (Glinde, Germany). High-producing cows were milked first in the morning and last in the evening. Daily milk yield was recorded using the ALPRO herd management system from DeLaval GmbH (Glinde, Germany). For analysis, cows were classified as high or low producing depending on mean daily milk yield in the first 42 days (high milk yield [HMY], $\geq$39 kg/day; low milk yield [LMY], $<$39 kg/day).

Visual heat detection and artificial insemination were carried out by the American Breeders Service (Hannover, Germany). Veterinarians from the Niedersachsen Extension Service (Oldenburg, Germany) carried out a reproductive examination between Days 10 and 14 pp. Depending on the reproductive health of the cows, they received veterinary treatment or were treated by the herd manager. Each cow received dinoprost (Dinolytic 25 mg im) on Day 21 pp. Cows with low-grade endometritis received another PGF2α injection on Day 35 pp. Cows with RFM were treated with tetracycline (Tetra-Sleecol 20,000 mg iu) on Day 4. Lochiometra was treated in the same way once or twice 3 days apart. Score 2 and 3 endometritis was treated with benzylpenicillin and streptomycin (Mastipencomp. 1850 and 1944 mg iu).

2.2. Study design

Cows underwent a clinical and sonographic examination between Days 268 and 272 of gestation. In four cows, the time of examination was not exactly defined because the date of artificial insemination was not known. The cows were also examined on Days 7, 14, 28, 42, and 56 pp (Day 0 = calving). After Day 43, cows were inseminated during spontaneous estrous cycles or they underwent an OvSynch protocol and fixed-time artificial inseminaition (AI). Cows that were not bred by Day 56 were examined sonographically every 10 days. Cows were examined sonographically for pregnancy 26 days after AI, and in pregnant cows, the vitality of the embryo was confirmed on Day 42. Examinations were discontinued on Day 42 when a cow was confirmed pregnant or on Day 150 in cows that failed to conceive. The examinations took place in a pen equipped with self-locking head gates. Lactating cows were brought to this pen directly after milking in the morning or in the evening.

2.3. Clinical and sonographic examinations

Each Doppler sonographic examination was preceded by a clinical examination according to Dirksen et al. [17]. Displaced abomasum was ruled out. All diseases that occurred in the study interval (until 150 days pp) were recorded.

The mammary gland was inspected and palpated, and milk samples from all quarters were evaluated macroscopically and with the California mastitis test. The pH was determined using indicator strips (Bovivet Indicator Paper, Kruuse, Langeskov, Denmark), and the somatic cell count was determined using the eimü Cell-Check 3S (Eimermacher GmbH & Co. KG, Nordwalde, Germany), which is a modified California mastitis test for early detection of mastitis [18].

The uterus was examined transrectally by manual palpation [17]. Size, symmetry, content, and contractility were assessed. The ovaries were palpated and examined sonographically for size and presence of a CL, follicles, and ovarian cysts. A diagnosis of RFM was made when the placenta was not expelled after 12 hours.