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Conversion of intraovarian patterns from preovulation to postovulation based on location of dominant follicle and corpus luteum in heifers

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ABSTRACT

The conversion of preovulatory intraovarian patterns based on location of the preovulatory follicle (PF) and the associated corpus luteum (cl) to postovulatory patterns based on location of the future and established dominant follicle (DF) and corpus luteum (CL) was studied daily in 26 heifers from Days −5 to 6 (Day 0 = ovulation). The two ipsilateral preovulatory patterns were PF–cl and devoid (neither PF nor cl), and the two contralateral patterns were PF and cl. The postovulatory patterns were DF–CL, devoid, DF, and CL. For the contralateral preovulatory relationships, a conversion from PF to DF–CL and the accompanying conversion from cl to devoid occurred most frequently (17 of 18 conversions, 94%). For the ipsilateral preovulatory relationships, a conversion from PF–cl to CL and from devoid to DF occurred most frequently (6 of 8, 75%). Number of 2-mm follicles during preovulation was greatest ($P < 0.05$) for the devoid and PF patterns, and number of 6-mm follicles during postovulation was greatest ($P < 0.05$) for the DF–CL and DF patterns. Blood flow resistance at a color Doppler signal in the ovarian pedicle indicated increasing ovarian perfusion over days in the PF to DF–CL and devoid to DF conversions and decreasing perfusion in the PF–cl to CL and cl to devoid conversions. In addition to formation of the CL from the PF, it was interpreted that the conversion of patterns involved number of newly emerging 2-mm follicles per ovary before ovulation and a continuation of the preovulatory angioarchitecture into postovulation. Results supported the novel hypothesis that the four preovulatory intraovarian patterns determine the frequency of the four postovulatory patterns.

1. Introduction

The periovulatory follicular wave or wave 1 in *Bos taurus* cattle emerges with 1- to 3- mm follicles before ovulation, during the ascending portion of a wave-stimulating FSH surge [1–3]. The follicular and hormonal characteristics of wave 1 have been studied most extensively using ovulation or emergence of follicles at 4 mm as a reference [4–6]. Most of the follicles that emerge at 4 mm develop during a common growth phase for 2 or 3 days and then deviate into a dominant and several subordinate follicles when the largest follicle is about 8.5 mm.

In single ovulators, four intraovarian patterns occur depending whether an ovary contains a corpus luteum (CL), dominant follicle (DF), both, or neither structure. The four intraovarian patterns refer to an ovary with a DF and CL (DF–CL), ovary with a DF alone (DF), ovary with a CL alone (CL), and ovary with neither DF nor CL (devoid) [7–9]. During the preovulatory period, the DF is the preovulatory follicle (PF) and similar terminology can be used by replacing DF with PF. The CL during preovulation is from the previous interovulatory interval (IOI). The ipsilateral

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relationship between a pair of ovaries consists of the intraovarian pattern of DF–CL and the requisite pattern of devoid in the opposite ovary. The contralateral relationship consists of the DF pattern in one ovary and the CL pattern in the other.

The reported intraovarian effects of CL on number of growing follicles have been contradictory [10]. In a recent report, the number of follicles 5 mm or larger in size during wave 1 was greater in ovaries with the DF (DF–CL and DF patterns), even when the DF was removed from the tally [10]. In a factorial analysis, there was a positive main effect of DF on number of follicles, but the main effect of CL and the interaction of DF and CL were not significant. It was concluded that a greater number of follicles are associated with the intraovarian presence of a future or established DF with or without the CL but not with the presence of only the CL. During anovulatory waves (e.g., wave 1), the DF–CL pattern and its companion pattern of devoid (ipsilateral relationship) occur more frequently than the DF pattern and CL pattern (contralateral relationship) [10].

The detection or emergence of 4- to 5-mm follicles in wave 1 occurs near the peak of the wave-stimulating FSH surge [1,2,4–6]. Smaller follicles (1–3 mm) emerge before ovulation during the ascending portion of the FSH surge [1]. A greater number of follicles in the PF ovary may increase the likelihood that the DF would develop in the same ovary and thereby increase the frequency of the DF–CL intraovarian pattern of wave 1 [10]. The developing CL is associated with increased vascularity of its ovary [11] but is not likely to further increase the number of follicles in the wave in that the number of follicles is affected by follicle dynamics before ovulation [10].

Blood flow and ovarian function based primarily on ultrasound transducers placed on the ovarian artery and infusion of radioactive microspheres in ewes [12] and the molecular and hormonal bases of the continued remodeling of the complex ovarian vascular system [13] have been reviewed. Transrectal color Doppler changes in the arteries of the preovulatory follicle and the developing CL have been described for cattle [11,14]. The hemodynamics of the developing CL and the future or established DF have been studied using color Doppler ultrasonography on Days 0 to 5 [15] (Day 0 = ovulation). A decrease in blood flow resistance index (RI) at the most prominent Doppler signal in an ovarian arterial branch before entry into the ovary indicates a downstream increase in the vascular perfusion to the ovarian tissue supplied by the branch. Vascular perfusion for each of four intraovarian patterns averaged over days decreased in the following descending order: DF–CL, CL, DF, and devoid. The differences in vascular perfusion began at the first assessment on Day 0 or 1, indicating that the postovulatory differences may be a reflection of events that occurred during the preovulatory period.

A two-way positive intraovarian effect or coupling occurs between the DF and CL when the two structures are adjacent [15]. Close proximity of the ipsilateral DF and CL is associated with greater diameter of DF, more blood flow signals in DF wall, larger area (cm^2) of CL, and more blood flow signals in CL. It has been interpreted that the DF and CL utilize common arterial branches so that a change in vascular perfusion of either structure is accompanied by a similar change in perfusion of the other structure when the structures are ipsilateral, especially when adjacent [15].

The present study considered whether the intraovarian patterns before ovulation influence the intraovarian patterns that develop after ovulation, beyond the requisite conversion of an ovary with the PF into an ovary with the CL. The mechanisms for conversion were considered with emphasis on number of follicles and the extent of vascular perfusion of various patterns. The hypothesis was that the four preovulatory intraovarian patterns determine the frequency of the four postovulatory patterns.

2. Materials and methods

2.1. Heifers

Bos taurus dairy heifers (Holsteins) aged 16 to 20 months were used (n = 26). The experiment was done during January through March in the northern temperate zone. The heifers were kept in an open shelter with natural light and were provided *ad libitum* access to water, trace-mineralized salt, and primarily grass hay. Grain supplementation consisted of 5-kg ground corn per heifer each day. The IOIs were not preceded by induced luteolysis, induced ovulation, or synchronization of estrus or ovulation, and the heifers were not bred. An IOI was not used if two ovulations occurred at the beginning of the IOI or if two dominant follicles (≥10 mm [16]) developed during wave 1. Heifers were handled in accordance with the United States Department of Agriculture Guide for Care and Use of Agricultural Animals in Research.

2.2. Terminology

The preovulatory period was defined retroactively as Days −5 to −1 and the postovulatory period as Days 0 to 6. The terminology for the ipsilateral and contralateral relationships between the two ovaries in the location of the PF or DF and the prevailing CL and for the intraovarian patterns of PF or DF and CL are illustrated (Fig. 1). The terminology “DF” is used for both the future DF between the days of ovulation and deviation and for the postdeviation DF. The study involved both the CL of the previous IOI during the preovulatory period and the CL of the postovulatory period. To minimize confusion, the CL from the previous IOI will be indicated by lower-case letters (cl) as shown (Fig. 1). The DF was identified as the largest follicle on Day 6 [5]. Although the DF was not firmly identifiable until after deviation in growth rates between the two largest follicles [6], the frequency of a follicle becoming the future DF began at 2 mm on the basis of the retroactive tracking records. The PF and cl during the preovulatory period and the DF and CL during the postovulatory period were used for defining intraovarian patterns.

2.3. Transrectal ultrasound scanning

A duplex B-mode (gray scale) and pulsed-wave color Doppler ultrasound instrument with a linear-array 7.5-MHz transducer was used for transrectal scanning. The identity of individual follicles of the periovulatory wave