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Bidimensional and Doppler ultrasonographic evaluation of postpartum uterine involution in the queen

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ABSTRACT

The aim of this study was to describe bidimensional and Doppler ultrasonographic changes of uterine involution during normal feline puerperium. Secondary, the postpartum vaginal discharge was described. Twelve pregnant female cats were included in this study. After queening, vulvar discharge was grossly and microscopically examined daily. Bidimensional and Doppler ultrasonographic examinations of the uterus were performed on Days −4 to −2, 4, 11, 18, and 25 from parturition. Total uterine diameter, uterine wall thickness, uterine lumen contents, peak systolic velocity, end diastolic velocity, and resistance index of uterine arteries were measured. The cats presented serosanguineous vulvar discharge for a mean of 3 ± 1 days after parturition, and the cytology revealed 70% to 80% of erythrocytes, which progressively decreased up to Day 13. Immediately after parturition, there were less than 20% neutrophils, and this percentage gradually diminished to 0% to 1% at the end of the study. Uterine total diameter diminished up to Day 25 ($P < 0.01$), when ultrasonographic uterine dimensions were similar to that of anestrus. A progressive decrease of uterine wall thickness ($P < 0.05$), uterine lumen contents ($P < 0.01$), peak systolic velocity ($P < 0.01$), and end diastolic velocity ($P < 0.01$) was found throughout the study period. Conversely, resistance index increased during the first week after parturition ($P < 0.01$). It is concluded that the uterine artery blood flow progressively decreased during the first 25 days after parturition, which was associated with the bidimensional ultrasonographic regression of the organ. Although lochial discharge disappeared far before ultrasonographic involution, cytologic findings further corroborated the duration of this regression process.

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1. Introduction

Puerperium is a physiological period after parturition in which uterine involution occurs. Complete uterine involution is essential for the establishment of future gestations. Furthermore, failure of normal uterine regression may lead to several diseases such as postpartum metritis and retained placenta in many mammalian species [1,2].

Ultrasonographic evaluation of the postpartum uterus is useful for monitoring its normal involution and for the early diagnosis of disorders. In female dogs, postpartum metritis is differentiated from the normal postpartum uterine enlargement by the failure of normal progressive decrease in uterine lumen contents and horn width [3]. Furthermore, the uterine wall can also be thickened or unusually irregular in these cases [4].

Doppler ultrasound has been used to assess postpartum uterine involution in women, cows, mares, and dogs [5–8]. A decrease in the blood flow of uterine arteries throughout puerperium has been reported in these species. Furthermore,

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Doppler uterine blood flow measurements are altered by puerperal uterine diseases in women and cows, contributing to the diagnosis of postpartum disorders [2,5,9].

Conversely to the previously mentioned species, the feline puerperium has been scarcely studied and some physiological aspects still remain obscure. For example, the duration of normal postpartum lochial discharge, which may be difficult to determine because of the frequent cleaning of the vulva after parturition, has not been reported in the queen. Although, and similar to other species, cytologic evaluation of this discharge might be useful for the early diagnosis of postpartum disorders [10,11], it has not been previously studied in the female cat.

Concerning ultrasonography, there has been reported only one bidimensional assessment of postpartum uterus in six queens [12]. In that study, only uterine diameter and wall thickness (WT) were measured, whereas luminal content dimensions were not reported. Moreover, there are no reports of the uterine perfusion as measured by Doppler ultrasonography during the feline postpartum period.

Thus, the aim of this study was to describe bidimensional and Doppler ultrasonographic changes of uterine involution during normal feline puerperium. Secondary, the postpartum vaginal discharge was grossly and microscopically described.

2. Materials and methods

2.1. Animals

Twelve pregnant short-hair domestic queens 1 to 4 years of age born in our institutional cat colony, weighing 2.5 to 3.9 kg, were included in this study. The animals were exposed to 10 hours of dark, 14 hours of light photoperiod and fed with dry commercial premium cat food and water *ad libitum*. Normal pregnancy was confirmed using two-dimensional ultrasonographic examination in all the cases [13]. This study was reviewed and approved by the Animal Care and Use Committee of the Veterinary School of the National University of La Plata, Argentina, and all experiments were conducted under the guidelines established in the Guide for the Care and Use of Laboratory Animals, USA.

2.2. Follow-up

Parturition occurred normally 64.4 $\pm$ 1.6 days after mating and was followed by an uneventful clinical puerperium in all cases [14]. The female cats delivered 2 to 6 kittens per queen which were weaned after the end of this study. Kitten birth weight was registered and averaged per litter. After queening, the queens were examined daily looking for the presence of vulvar discharge. Every other day, the external or vaginal discharge was collected by a swab. The discharge was then smeared on a slide, stained (Tinción 15, Biopur, Santa Fe, Argentina), and observed (magnification: $\times$ 400) using light microscopy. The percent erythrocytes, neutrophils were determined by counting a minimum of 100 cells (including vaginal epithelial cells) in each discharge smear.

2.3. Ultrasonographic evaluations

Ultrasonographic examinations were performed on Days -4 to -2, 4, 11, 18, and 25 (Toshiba Core Vision Pro, Japan) with an 8-MHz linear-array transducer. Day 0 was defined as the day of parturition. The female cats were positioned in lateral recumbency, and the hair of the ventral skin was clipped. The female cats were gently restrained in lateral recumbency without sedation, and the hair of the ventral skin was clipped after 5 minutes of acclimatization. Acoustic gel was applied to the transducer and coupled directly to the skin. Two-dimensional ultrasonography was used to identify the uterine body in a transverse axis. Both uterine horns were assessed immediately cranial to the uterine body bifurcation [15]. Total uterine diameter (TD; mm), uterine WT (mm), and uterine lumen contents (ULCs; mm) were measured in the transverse section of the left and right uterine horns [12]. Total uterine diameter was defined as the serosal to serosal distance [12], the uterine WT consisted of the serosal surface to the endometrial and uterine luminal interface [12], whereas all intraluminal contents were called uterine luminal contents. All measurements were taken as leading edge to leading edge.

Left and right uterine arteries were localized at both sides of the uterine body with color flow mapping, and pulsed-wave Doppler was used to obtain the waveforms [16]. To minimize variability, three uniform consecutive waveforms were recorded by a trained operator. Measurements having an angle of insonation greater than 20° were disregarded. Peak systolic velocity (PSV) and end diastolic velocity (EDV) were measured in both arteries. Resistance index [(PSV−EDV)/PSV] was automatically calculated [17].

2.4. Statistical analysis

Total uterine diameter, WT, and ULC of the left and right horns were compared using a Student's *t* test. Peak systolic velocity, EDV, and RI of the left and right uterine arteries were also compared by the same test. Repeated-measures ANOVA followed by the Tukey test was carried out to evaluate the effect of time on the six response variables using litter size, gestational length, and averaged birth weight as covariates (SPSS 18.0; SPSS, Chicago, IL, USA). Pearson's correlation analyses were carried out between RI and each of the three uterine measurements i.e., TD, WT, and ULC. The level of significance was set on $P < 0.05$.

3. Results

The cats presented serosanguineous vulvar discharge for a mean of 3 $\pm$ 1 (range, 2–6) days after parturition, and the cytology revealed 70% to 80% of erythrocytes, which progressively decreased up to Day 13. Immediately after parturition, there were less than 20% neutrophils, and this percentage gradually diminished to 0% to 1% at the end of the study.

Each ultrasonographic evaluation was successfully performed in less than 15 minutes. No differences were found between left and right uterine horns and arteries ($P > 0.1$),

therefore, values of TD, WT, ULC, PSV, EDV, and RI were averaged. A progressive decrease of TD ($P < 0.01$), WT ($P < 0.05$), and ULC ($P < 0.01$) occurred in the course of puerperium in all the cases (Fig. 1). Litter size, gestational length, and averaged birth weight did not influence the ultrasonographic parameters ($P > 0.1$).

In the first postpartum observation (Day 4), the uterine luminal contents were of a mixed echogenic pattern appearing both hypoechoic and moderately echoic components. The hypoechoic zone, between the endometrium and the ULC, was considered fluid. Uterine wall and ULC could not be ultrasonographically differentiated from Day 18 onward.

A gradual diminution of PSV ($P < 0.01$; Fig. 2) and EDV ($P < 0.01$; Fig. 2) was found throughout the study period. Conversely, RI increased during the first week after parturition ($P < 0.01$; Fig. 1). Correlations between RI and TD, WT, and ULC were $r = -0.32$ ($P < 0.01$), $r = -0.41$ ($P < 0.01$), and $r = -0.09$ ($P < 0.01$), respectively.

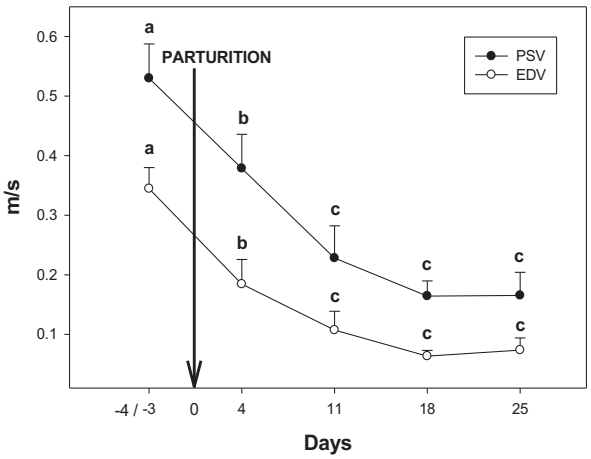

Fig. 2. Peak systolic velocity (PSV; mean ± standard error of the mean [SEM]) and end diastolic velocity (EDV; mean ± SEM) of the same animals of Figure 1. For each variable, different letters indicate differences ($P < 0.01$) among days.

4. Discussion

To our knowledge, this is the first report of cytologic and uterine Doppler assessment during the uncomplicated feline postpartum period. In agreement with what has been described for other mammalian species [6,8], uterine dimensions and blood flow decreased throughout the study period.

Although vulvar discharge was observed in the study population for only 2 to 6 days after labor, erythrocytes were present up to Day 13 in the smears. It has been reported that neutrophils are observed throughout the estrous cycle representing less than 30% of the observed cells in feline smears [14]; similar information during the puerperal period is lacking. In these queens, neutrophils progressively diminished and were observed up to Day 25 in some animals. These results are consistent with what has been described for bovine puerperium, where neutrophil count decreased after parturition in normal animals [18].

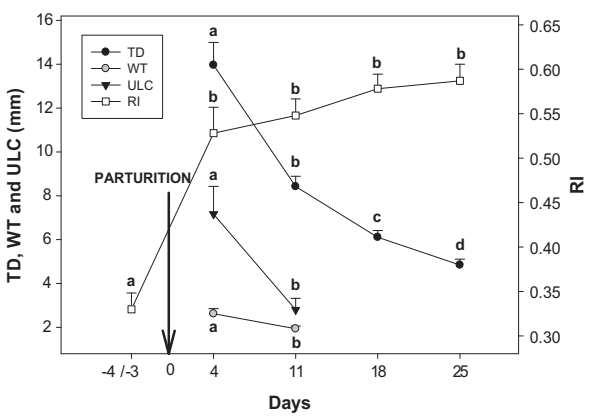

Fig. 1. Total uterine diameter (TD; mean ± standard error of the mean [SEM]), uterine wall thickness (WT; mean ± SEM), uterine lumen content (ULC; mean ± SEM), and resistance index of uterine artery (RI; mean ± SEM) of 12 queens before and after parturition (Day 0). For each variable, different letters indicate differences ($P < 0.01$) among days.

Although postpartum involution appeared complete by the fourth week, histologic verification of this finding is needed.

The uterine TD and WT found in this study were similar to those previously reported by Ferretti et al. [12] for feline puerperium. Uterine TD diminished up to Day 25, when ultrasonographic uterine dimensions were similar to those of anestrus registered in this study population (6.3 ± 0.6 mm; unpublished observations). A previous hysterographic report in this species stated that uterine diameter was not different from that of anestrus when measured between 1 and 2 months after parturition [19]. This discrepancy between studies could be due to the different techniques used as well as to the length from queening and the infrequent observations carried out by Chatdarong et al. [19].

In the present study, uterine wall and luminal contents were detected up to Day 11 after parturition. Although Ferretti et al. [12] could distinguish uterine wall on Day 14 after parturition, in the present study, this structure was no longer detected from Day 18 onward when the whole uterus showed a hypoechoic image similar to that of anestrus [20]. This apparent dissimilarity might be due to the different observation time points between studies.

Cats seem to have more rapid postpartum uterine involution than dogs, another species with endotheliochorial placentation [21]. In a canine study, uterine ultrasonographic appearance became indistinguishable from that of anestrus on Day 52 after parturition [8] versus Day 18 in this feline study. This rapid involution, which may be due to histologic differences between both species [22,23], clearly favors the prompt possibility to get pregnant again. Importantly, postpartum uterine diseases are less frequent in cats than in dogs. The rapid feline uterine involution surely contributes to this lower prevalence.

Uterine wall layers after parturition also seem to differ between dogs and cats. Up to five ultrasonographically distinct layers have been identified in the postpartum canine uterine wall [15], whereas only three layers could be detected in this and the previous feline study [12].

Moreover, uterine WT is markedly thinner in cats than in dogs [19,24].

As expected, RI of uterine artery increased, whereas both PSV and EDV decreased up to Day 11. Furthermore, although weak, correlations between RI and the bidimensional parameters were found. These findings evidenced a vascular involution associated with the morphologic changes of the organ.

A marked decrease in uterine blood flow during the first postpartum week has also been described in bovine and canine puerperium [6,8]. The short 11-day vascular involution observed here is in agreement with the rapid return to fertility that characterizes feline species. Kitten number and birth weight did not significantly influence ultrasonographic parameters, although experiments with a larger number of queens are needed to test this influence.

In this study, ultrasonographic uterine involution was completed by Day 25 after parturition. The same as in women, cows, mares, and bitches, clinical evidence of involution disappeared before the ultrasonographic evidence of involution [5–8]. Further work is still necessary to determine if, in cats, histologic involution exceeds ultrasonographic puerperium.

Doppler ultrasound seems to be a useful tool for assessing uterine involution during physiological feline puerperium. The present report provides basic information for the future study of postpartum disorders.

4.1. Conclusions

It is concluded that the uterine artery blood flow progressively decreased during the first 25 days after parturition, which was associated with the bidimensional ultrasonographic regression of the organ. Although lochial discharge disappeared far before ultrasonographic involution, cytologic findings further corroborated the duration of this regression process.

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Competing Interests

None of the authors of this article has a financial or personal relationship with other people or organizations that could inappropriately influence or bias the content of the paper.

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