Effects of age, parity, and pregnancy abnormalities on foal birth weight and uterine blood flow in the mare

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Abstract
Color Doppler sonography has become routine for the evaluation of high-risk pregnancies in human medicine. Previous studies documenting uterine blood flow parameters in the pregnant mare have found a decrease in peripheral blood flow resistance in the first pregnancy weeks and an increase in uterine blood flow, especially in the last trimester of pregnancy. However, these studies involved only a small number of mares. No naturally occurring pregnancy abnormalities occurred that would allow blood flow changes to be retrospectively examined and analyzed. The objective of the present study was to monitor the diameter of the uterine artery, uterine blood flow, and the combined thickness of the uterus and placenta (CTUP) throughout gestation in a large number of pregnant mares of different age and parity.

In the present study, 51 warmblood mares were examined by ultrasonography on Days 16 and 30, at monthly intervals until Day 300, and then every 10 days from Day 300 until parturition. After localization of the uterine artery ipsilateral and contralateral to the conceptus, the diameter of each artery, the uterine blood flow (pulsatility index [PI], blood flow volume [BFV], and the presence of early diastolic notch), and the CTUP were measured and correlated to placental and foal birth weight after delivery. Furthermore, the effect of age (3–7 years [n = 16], 8–11 years [n = 17], 12–16 years [n = 18]) and parity (0–2 foals [n = 22], 3–4 foals [n = 15], 5–8 foals [n = 14]) on these parameters were analyzed. The diameter of the uterine artery increased more than threefold in the ipsilateral artery (0.40 ± 0.07 to 1.33 ± 0.08 cm) and 2.7-fold in the contralateral artery (0.39 ± 0.07 to 1.07 ± 0.08 cm [P < 0.0001]). The early diastolic notch disappeared in the pulse waves in 98% of the ipsilateral arteries and 85.7% in the contralateral arteries on Day 150 when placentation is complete. Blood flow volume increased 50-fold in the ipsilateral artery during pregnancy and increased dramatically in the last trimester. The median foal weight was 52.6 kg. Mares with heavier foals (>52.6 kg) had a 1.38-fold higher BFV in the last 2 months (P < 0.05) compared with lighter foals. Pulsatility index decreased 2-fold until completion of placentation at around Day 150 and continued to decline until Day 240 where it then stayed constant and at a low level until delivery. Age predominantly influenced PI, whereas the diameter of the uterine arteries, which is correlated to BFV (r ipsilateral = 0.919, P < 0.0001 and
1. Introduction

Identification of high-risk pregnancies has aroused the interest of researchers and clinicians because advances in ultrasonographic technology which have facilitated improved pregnancy monitoring, identification of fetal well-being, and diagnosis of placentitis and other diseases in the pregnant mare [1,2]. In human medicine, color Doppler sonography has become routine for the diagnostic evaluation of high-risk pregnancies [3–5]. Bollwein et al. [6,7], Ousey et al. [8,9], and Bailey et al. [10,11] analyzed blood flow parameters during equine pregnancies. The Doppler sonographic studies illustrated a decrease in the peripheral blood flow resistance in the first weeks of pregnancy and an increase in uterine blood flow volume (BFV), especially in the last trimester of pregnancy. However, in all these studies, mare numbers were low and no naturally occurring pregnancy abnormalities were observed.

Low birth weight has long been associated with equine neonatal illness [12–15]. The placental influence on foal birth weight was sonographically examined in B mode during pregnancy [2,16] and histologically evaluated after delivery [17–19]. The gross area of the allantochorion (AC) and its macroscopic and microscopic architecture have been positively correlated with foal birth weight [17,20,21].

In aged mares with endometriosis, placental development is compromised by poor interdigitation and attachment between the AC and the luminal surface of the endometrium [20]. Ousey et al. [9] grouped 12 pluriparous Thoroughbred mares according to age and endometrial biopsy scores. There was a tendency for lower total BFV in older mares (mean age, 18.3 years; Category II), and these mares delivered significantly lighter foals than younger mares (mean age, 7.3 years; Category I). The absence of higher resistance indices in older mares was explained by the relatively minor pathologic changes in the endometrial vasculature of the six older mares.

The aim of the present study was to monitor the diameter of the uterine artery (DUA), uterine blood flow, and the combined thickness of the uterus and placenta (CTUP) in a group of 51 warmblood mares throughout gestation.

2. Materials and methods

2.1. Animals

Fifty-one pregnant warmblood mares were examined from Day 16 after ovulation until parturition. The mares were located on the same farm and were maintained at pasture during the summer months and stabled during the winter months. There were 39 mares with foals, 10 barren, and two maiden mares which were all fed concentrates, hay, and silage. The horses were between 3 and 16 years old and had had up to eight foals with 3.3 foalings on average. Mares with foals were examined daily during foal heat and inseminated with fresh or cooled, stored, shipped semen from one of eight stallions. If ovulation took place before Day 10 after parturition, they were inseminated in the following cycle. Maiden and barren mares were inseminated at the first observed cycle of the breeding season. Pregnancy and location (side) of the embryonic vesicle were determined by transrectal linear ultrasound on Days 14 to 16 after ovulation.

2.2. Uterine artery diameter and blood flow

The mares were examined by ultrasonography on Days 16 and 30, and at monthly intervals until Day 300 of gestation. After Day 300, ultrasound examination was performed every 10 days until parturition. Uterine blood flow was studied in both uterine arteries, ipsilateral and contralateral to the conceptus as previously described [6,10]. Measurements were obtained using color flow and pulsed wave Doppler with a 4- to 10-MHz endolinear probe (LOGIQ e ultrasound; GE Healthcare, Munich, Germany). The uterine artery was identified close to its origin from the external iliac artery at which point the diameter (DUA) was determined. The on-screen Doppler gate was positioned over the artery and the probe rotated to an angle of 20°, and a consistent spectral display was obtained. Qualitative analysis of the spectral waveforms included detection of negative and positive diastolic blood flow and the early diastolic notch. Doppler indices measured from two consecutive spectral waveforms using the software PixelFluxScientific (Fa. Chameleon Software, Leipzig, Germany) included the time-averaged maximum frequency shift over the cardiac cycle and the time-averaged maximum velocity. The pulsatility index (PI) was calculated as a proportion of the uterine impedance and the uterine BFV (BFV = time-averaged maximum velocity × uterine artery area). Blood flow volume of both uterine arteries were added together to calculate the total BFV (BFVtotal). Furthermore, the presence of the early diastolic notch was documented as described by Thaler et al. [22].
2.3. Combined thickness of uterus and placenta

From Day 150 until parturition, the CTUP was determined by B-mode ultrasound at monthly intervals from Days 150 to 300 and then at 10-day intervals from Day 300 until parturition as described previously by Renaudin et al. [2].

2.4. Gestation length, placental weight, and foal birth weight

After delivery, the placental membranes were collected and weighed. The amnion was removed, and the weight of the AC was determined. The AC thickness was measured at the cervix and in the pregnant horn. Neonates underwent a physical examination at birth [23,24]. The birth weight of the foals was recorded within four hours after delivery.

2.5. Statistical analysis

Statistical analyses were conducted using PASW Statistics 18 (SPSS Inc., Munich, Germany) with significance levels of P less than 0.05. The Kolmogorov–Smirnov test was used to test for normality of data. Means and standard deviation were calculated for all previously mentioned normally distributed parameters. To examine the influence of age and parity on blood flow parameters, the mares were divided into three groups according to the number of previous foalings (group 1: 0–2 foals, n = 22; group 2: 3–4 foals, n = 15; and group 3: 5–8 foals, n = 14) and age (group 1: 3–7 years, n = 16; group 2: 8–11 years, n = 17; and group 3: 12–16 years, n = 18). This division was chosen to reach similar numbers in each group.

Foals were divided into two groups depending on the median of their birth weight (heavy foals > 52.6 kg; light foals < 52.6 kg).

Differences between two groups were estimated using post hoc test (Ryan-Einot-Gabriel-Welsh range test and Gabriel procedure) and Pearson correlation coefficients were calculated between the parameters.

3. Results

3.1. Diameter of the uterine artery

The DUA increased linearly from Day 16 until Day 310 and remained constant until parturition. The diameter of the ipsilateral uterine artery increased more than threefold from 0.4 ± 0.07 cm to 1.33 ± 0.08 cm (P < 0.0001), and the diameter of the contralateral artery increased 2.7-fold from 0.39 ± 0.07 cm to 1.07 ± 0.08 cm (P < 0.0001). Differences in the DUA were observed between the different age groups. The study included a four-year-old and a six-year-old maiden mare, which showed an increase from 0.29 to 1.08 cm and 0.25 to 1 cm in the diameter of the ipsilateral uterine artery, respectively. Mares older than 7 years had significantly larger diameters in both arteries (Fig. 1A).

Most striking was the correlation between DUA of both arteries and parity (Day 16: ipsilateral r = 0.49, contralateral r = 0.48; Day 210: ipsilateral r = 0.65, contralateral r = 0.56; and Day 340: ipsilateral r = 0.7, contralateral r = 0.48; P < 0.05, Fig. 2A).

The parameters, DUA, PI, BFVtotal, and foal birth weight, were mostly influenced by gestational age. A variability of 6.8% in the diameter of the ipsilateral uterine artery between mares was explained by mare’s age (19.1%), parity (42.9%), and the interaction of age and parity (37.3%).

3.2. Uterine blood flow

Negative diastolic blood flow was detected at least once in all 22 mares before Day 60. On Day 90, all mares showed pulse waves with only positive diastolic blood flows. The early diastolic notch disappeared from the ipsilateral uterine artery on Days 60 (n = 5; n = number of mares), 90 (n = 8), 120 (n = 16), 150 (n = 19), and 180 (n = 1), whereas it was detected in the contralateral artery until Days 60 (n = 1), 90 (n = 4), 120 (n = 16), 150 (n = 21), 180 (n = 4), and 210 (n = 3). By Day 150, when placentation is completed, the diastolic notch had disappeared in 98% of mares on the ipsilateral uterine artery and in 85.7% of mares on the contralateral uterine artery.

Blood flow volume increased during pregnancy (P < 0.05). The BFV of the ipsilateral artery increased 50-fold between Day 16 (2.5 ± 0.98 mL/s) and the last examination before parturition (124.4 ± 32.8 mL/s), whereas the BFV of the contralateral artery increased 33-fold (2.32 ± 0.89 vs. 77.84 ± 20.0 mL/s) during this same time period.

A moderate correlation (r = 0.48, P < 0.01) between BFVtotal in the last month of pregnancy and foal birth weight was observed. The median foal weight was 52.6 kg. Mares with heavier foals at birth (>52.6 kg) had a 1.38-fold higher BFVtotal in the last 2 months of pregnancy (P < 0.05). Total BFV was not affected by age of the mare (Fig. 1B). Only on Day 16 did older mares (>8 years) have a significantly higher BFVtotal. Additionally, BFVtotal was moderately correlated to parity in the first and last months of pregnancy. Mares with more than two previous foalings had a significantly higher BFVtotal in the last 2 months compared with mares with 0 to 2 previous foalings (Fig. 2B).

A variability of 2.5% in BFVtotal between the mares was explained by mare’s age (46.1%), parity (26.4%), and an interaction of age and parity (27.5%).

Pulsatility index decreased most strikingly in the first trimester of pregnancy (PIipsi; 1.9 ± 0.5 on Day 16 vs. 0.6 ± 0.1 on Day 340). Pulsatility index decreased 2-fold until completion of placentation around Day 150 and then further declined until Day 240 (P < 0.05) where it stayed at a constant low level until delivery.

Differences in the PI between the ipsilateral and contralateral arteries were not significant. Resistance in the uterine artery was significantly higher in mares greater than 7 years of age, especially in the first half of pregnancy (Fig. 1C). Previous foalings increased the PI in the ipsilateral artery in the first trimester, whereas they did not show a significant influence later on in gestation (Fig. 2C).

A variability of 2.0% in the uterine artery resistance between mares was explained by mare’s age (0.7%), parity (76.4%), and the interaction between age and parity (32.9%).
3.3. Combined thickness of uterus and placenta

The increase of CTUP was nonsignificant (25.8%) from Days 150 (0.31 ± 0.04 cm) to 210 (0.39 ± 0.09 cm) but distinctly increased (100%; P < 0.05) from Day 240 (0.48 ± 0.13 cm) to the last examination (0.96 ± 0.23 cm). Two mares showed an increased CTUP. One mare with a CTUP of 1.26 cm on Day 240 was treated for placentitis with antibiotics and nonsteroidal anti-inflammatories and delivered a viable foal on Day 340. Another mare with increased CTUP on Day 310 (1.37 cm) also had an increased AC weight (4.5 kg) and delivered a dysmature foal with a meningocele which was euthanized after birth. Combined thickness of uterus and placenta was higher in older mares throughout pregnancy and significantly greater on Days 180 and 320 (P < 0.05). Combined thickness of uterus and placenta was not influenced by parity.

3.4. Gestation length, placental weight, and foal birth weight

Forty-four of the 51 pregnant mares delivered a live foal after a gestational length of 340 ± 8.4 days (301–351 days). Two mares lost their pregnancy before Day 60, four mares aborted, and one foal died after dystocia and delayed delivery. The average placental weight was 5.3 ± 1.3 kg, and the average AC weight was 3.4 ± 0.8 kg. Correlations of r = 0.58 and 0.46 were observed between the AC weight and the AC thickness at both the cervix and the pregnant horn, respectively (P < 0.0001). Fetal membranes from three mares showed an increased AC weight (5.1 kg, 4.5 kg, and 5.9 kg) and evidence of placentitis.

While there was no significant correlation between birth weight and gestational length (P > 0.05), a positive correlation (r = 0.35, P < 0.05) between parity of the mare
and birth weight was observed (Fig. 3A). Foals from age group 2 mares (8–11 years) showed a higher (P < 0.05) birth weight than foals from younger and older mares (Fig. 3B). A variability of 27.7% in foal birth weight between mares was explained by mare age (6.5%), parity (55.3%), and an interaction between age and parity (38.3%).

3.5. Abortion and placentitis

Four mares aborted and four mares developed placentitis during the study. Case numbers were too low to result in significant observations; however, differences in uterine blood flow have been observed. The four mares aborted on Days 200, 208, 213, and 246 without clinical signs of placentitis or general disease. The etiology of the abortions remained unknown. However, an increased BFVtotal was observed preceding all the abortions. The early diastolic notch disappeared in aborting mares in the ipsilateral/contralateral uterine artery for one mare on Day 150 (ipsilateral)/Day 210 (contralateral), for two mares on Day 90/Day 120, and the other mare on Day 150/Day 210.

One mare delivered a live immature foal on Day 301, which died within the first day of life. The placenta was edematous and weighed 9.4 kg compared with a mean weight of 5.3 ± 1.3 kg. Mares that developed placentitis in the late gestation had an increased PI in the ipsilateral artery in the first half of pregnancy, but no changes were detected in the PI of the contralateral uterine artery or in the total BFV. The early diastolic notch disappeared in the ipsilateral/contralateral uterine artery in one mare that developed placenta in late gestation on Day 150 (ipsilateral)/Day 210 (contralateral) and in three
mares on Day 150 in the ipsilateral/contralateral uterine artery.

4. Discussion

4.1. Uterine blood flow

This is the first large-scale study to document uterine blood flow changes throughout the gestational period by color flow and pulse wave Doppler sonography in 51 pregnant mares. Previous studies have reported similar findings but were carried out on a much smaller number of mares [6,7,9,10,25].

Uterine impedance, which was determined by measurement of PI, declined during gestation but especially during the first trimester. As a reverse (negative diastolic), uterine blood flow was observed during pulse waves in the first 30 days of pregnancy. Pulsatility index instead of resistance index was used as a parameter for uterine impedance. During early pregnancy, the noninvasive trophoblast of the equine AC lies in apposition but not intimately associated with the endometrium resulting in increased uterine vascular impedance. This was seen in 22 of the mares that had a high PI and a negative diastolic blood flow until Day 60. Ousey et al. [9] did not detect a reverse blood flow but occasionally observed spectral waveforms with absent early diastolic flow during early pregnancy (<Day 56). Pulsatility index then decreased during placentation with increased angiogenesis beginning around Day 40 [26] until placentation was completed (around Day 150 in the mare), and the PI then stayed at a low level until parturition (0.6 ± 0.1).

In human pregnancies, another sign of a decrease in blood flow resistance is the disappearance of the early diastolic notch [27,28], which disappeared between Days 60 and 180 and Days 60 and 210 in the ipsilateral and contralateral uterine artery, respectively, in our study. Prolonged display of the notch is a sign of lower uterine perfusion and associated with disorders in human pregnancies. Mares that developed placentitis in advanced pregnancy showed a late (Days 150–210) disappearance of the early diastolic notch. As far as we know, this is the first observation of the presence of a late diastolic notch in mares which naturally developed placentitis. Future studies are required to confirm the relevance of this finding in abnormal pregnancies in the mare.

During pregnancy, an almost linear increase in DUA occurred until Day 310 which resulted in a 50-fold increase in BFV. Similar to Bollwein et al. [6,7], who observed a fivefold increase from 3 to 15 mm, the DUA increased fourfold from 4 to 16 mm during gestation in mares in our study. The slightly different findings may be contributed to the reproductive history of the mares in which Bollwein examined two maiden and three pluriparous mares. In this study, the uterine artery diameters of only two maiden mares and 39 mares with foals were evaluated. The mares with foals might had an incomplete uterine involution after foaling the same season.

The changes seen in uterine blood flow during pregnancy were also correlated with placental and fetal development. The distinct rise in BFVtotal in the last trimester was consistent with fetal growth as the metabolic demands of the fetal tissues increase [29,30]. The fetus grows exponentially in the last trimester, and this striking increase in weight is associated with an increase in BFVipsi in the last trimester. Mares with heavier foals at birth (>52.6 kg) had a significantly higher BFVtotal in the last 60 days of pregnancy. This observation has also been made in cows. Herzog et al. [31] examined cows in the second half of the pregnancy and observed a linear increase of BFV that was 43% higher than BFVipsi in the last 60 days of pregnancy. This observation has also been made in cows. Herzog et al. [31] examined cows in the second half of the pregnancy and observed a linear increase of BFV that was 43% higher in BFVipsi in the last trimester. Mares with heavier foals at birth (>52.6 kg) had a significantly higher BFVtotal in the last 60 days of pregnancy. This observation has also been made in cows. Herzog et al. [31] examined cows in the second half of the pregnancy and observed a linear increase of BFV that was 43% higher in cows giving birth to a heavy calf compared with those that produced a lighter calf. Cows with different body weights but same birth weight of calf showed no differences in BFV. However, cows with the same body weight but giving birth to a heavy calf showed a significant rise in BFV.

In contrast to the observations of Ousey et al. [9], a greater increase in BFV of the ipsilateral uterine artery (50-fold increase during pregnancy) compared with the contralateral uterine artery (33-fold increase during pregnancy) was observed in the present study and was associated with an increase in the blood vessel diameter. Pulsatility index did not change significantly between both arteries.

4.2. Effect of age and parity

In the present study, BFV, PI, and DUA significantly increased with the number of previous foalings. In particular
was a high correlation between $D_{UA}$ of both arteries and parity. Two maiden mares had a uterine artery diameter of 0.29 and 0.25 cm which was significantly smaller compared with the mean uterine artery diameter of the rest of the mares in the study (0.4 ± 0.07 cm). This difference in uterine artery diameter and parity is most likely contributed to the incomplete uterine involution after delivery thereby resulting in an increasing blood vessel diameter and BFV after each foaling.

Age predominantly influenced uterine resistance in the present study. Pulsatility index in the uterine artery was significantly higher in mares greater than 7 years, especially in the first half of pregnancy. Whereas Woschee [32] did not observe a relationship between age and PI; Bollwein et al. [33] reported a higher resistance in older mares. This increase in PI was contributed to significant age-related alterations in endometrial vessels (fibrosis and angiosclerosis), which led to reduced elasticity. Similarly, Blaich et al. [25] detected higher PI values in mares with endometriosis. A correlation between alterations in the endometrial vessels and alterations in the uterine artery might allow the use of uterine biopsy as a diagnostic tool for prognosis of uterine artery structure [34].

Besides vessel alterations, older mares are more susceptible to the development of endometrial cysts and periglandular fibrosis which is associated with reduced fetomaternal contact.

Contrary to a recent study by Ousey et al. [9], who observed higher BFV in younger mares, there was no significant difference in BFV between the young and old mares in the present study. This difference may be attributed to the different age classifications in each of the studies. The oldest mare in the present study was only 16 years, Ousey et al. examined mares with a mean age of 18.3 years in the older group.

The intensive breeding management of the mares in this study may have also contributed to differences seen in blood flow parameters. The mean parity of mares in our study was 3.3 with older mares having up to eight previous foalings. Mares older than 7 years in general had more previous foalings causing larger diameters of both uterine arteries, which lead to a higher BFV. Two-way ANOVA was used to analyze interactions between age and parity. A variability of 6.8% in the diameter of the ipsilateral uterine artery was contributed to mare age (19.1%), parity (42.9%), and the interaction of age and parity (37.3%). Further studies including older maiden mares and mares with delayed breeding activity might help to distinguish the effect of age and parity.

Uterine blood flow and uterine artery diameter influenced the foals’ birth weight. In the present study, increased BFV was associated with higher foal birth weights in mares with an increasing number of previous foalings ($r = 0.35, P < 0.05$). Elliott et al. [35] also documented this relationship between foal birth weight and mare parity and determined an increase in foal birth weight of 0.8 kg per pregnancy. Wilsher and Allen [18] observed an 18% increase in foal birth weight from 46.9 ± 0.1 kg in the first pregnancy to 54.8 ± 1.7 kg in the second successive pregnancy. This increase was contributed to an increase in the microcotyledon density and surface area per unit volume. The authors concluded that the uterus needs to be “primed” by the first pregnancy for full potential microcotyledon development.

Ousey et al. [9] observed an increased foal weight in younger mares. In the present study, mares aged from 8 to 11 years delivered significantly heavier foals compared with younger and older mares. Wilsher and Allen [18] explained this observation by concluding that older mares may suffer from endometrial degeneration, whereas younger mares had less previous pregnancies and thus lower fetomaternal contact.

In conclusion, age seemed to predominantly influence PI, whereas diameter of uterine arteries was strongly affected by parity. Because blood vessel diameter correlates with uterine blood flow, BFV is influenced by parity. Whereas PI does not significantly decrease after completion of placenta; BFV rises with fetal growth in the last trimester. A positive correlation between birth weight and BFV in the last month of gestation was found.

4.3. Abortion and placentitis

In this study, we were able to opportunistically detect and monitor four mares that spontaneously aborted and four mares that developed placentitis. As far as we know, these are the first observations of naturally occurring pregnancy disorders in the mare, which were monitored by regular uterine blood flow measurements throughout pregnancy. Case numbers were too low to result in significant observations; however differences in uterine blood flow could be observed.

The etiologic reason of the abortions on Days 200, 208, 213, and 246 could not be determined. Surprisingly, the aborting mares showed a tendency of increased BFVtotal and a normal PI in the later gestation until the day of abortion. An explanation could be a “rebound effect” via secretion of vasodilators in the compromised foal. Decreased fetal perfusion might result in the secretion of vasodilators such as vascular endothelial growth factor. Vascular endothelial growth factor is a potent stimulator of angiogenesis [36]. It has been shown to be expressed in endometrium, decidua, and trophoblast of human and nonhuman primates and the placenta of sheep and pig [37,38], and its synthesis is stimulated by hypoxia [39,40].

Four mares developed placentitis without typical presenting clinical signs (vaginal discharge, premature udder development, and pyrexia). In these cases, placentitis was detected by an increased CTUP on Days 240 and 310 of pregnancy, respectively, or after delivery of edematous fetal membranes and a dysmature foal. The etiology of the relatively high incidence of naturally occurred placentitis in the population of mares in the present study is unknown. However, three of the four mares with placentitis were older than 12 years and had more than three previous foalings. Older pluriparous mares are more susceptible to ascending infection because of an impaired cervical and vulvar closure [41].

Interestingly, mares that developed placentitis later in gestation displayed an increased PI in the first half of pregnancy. In human medicine, alterations in the placenta
(e.g., premature placental detachment) are detected by an increase in uterine resistance [42–44]. Bailey et al. [11] recently induced placentitis in six pony mares, which was detected by increased CTUP within 3 days after inoculation. Although these mares were examined ultrasonographically at very regular intervals (12 hours for 5 days, 24 hours for 8 days, and 48 hours until delivery), Doppler ultrasonographic measurements of resistance index, PI, and total arterial blood flow did not reveal differences between the infected and uninfected mares.

In conclusion, this is the first large-scale study in mares to not only document “physiological” blood flow changes throughout gestation but also to document the impaired uteroplacental blood flow in naturally occurring abortion and placentitis cases for the first time. Further studies in this area will involve monitoring mares with a history of abortion and placentitis at regular intervals throughout pregnancy. Regular uterine blood flow measurements in mares predisposed to developing complications during pregnancy combined with ultrasonographic monitoring of fetoplacental well-being may facilitate the early detection and initiation of treatment of a compromised/impaired pregnancy which will in turn may increase the chance of delivery of a live and vital foal.

References


