Theriogenology 83 (2015) 721–729

Contents lists available at ScienceDirect

Theriogenology

journal homepage: www.theriojournal.com

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

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ARTICLE INFO

*Article history:*
Received 2 July 2014
Received in revised form 3 November 2014
Accepted 4 November 2014

*Keywords:*
Doppler sonography
Pregnancy
Uterine blood flow
Foal weight
Placentitis
Combined thickness of the uterus and placenta

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 ± 0.07–1.33 ± 0.08 cm) and 2.7-fold in the contralateral artery (0.39 ± 0.07–1.07 ± 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

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http://dx.doi.org/10.1016/j.theriogenology.2014.11.007

$r$ contralateral = 0.909, $P < 0.000$), was strongly affected by parity. Four mares spontaneously aborted (Days 200, 208, 213, and 246) and four mares spontaneously developed placentitis that was diagnosed by the presence of an increased CTUP and/or placental pathology after delivery. Although not statistically relevant, the aborting mares showed a slightly increased total BFV, but no differences in PI were seen compared with mares without abnormalities of pregnancy. Mares that developed placentitis had a late (Days 150–210) disappearance of the early diastolic notch and an increased PI in the first half of pregnancy. In conclusion, the study documented differences in uterine artery diameter and blood flow in a large number of pregnant mares. Furthermore, this is the first known report to document uteroplacental blood flow changes associated with naturally occurring placentitis and abortion in mares.


## 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 ($D_{UA}$), 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 ($D_{UA}$) 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 ($BFV_{total}$). Furthermore, the presence of the early diastolic notch was documented as described by Thaler et al. [22].