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Doppler Ultrasonographic Evaluation of Maternal and Foetal Blood Flow in Bitches Approaching Delivery by Different Whelping Modes

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ABSTRACT

Present study included 28 healthy bitches which, based on modes of whelping, were divided into four groups viz., Group I (Vaginal whelping/VW), Group II (elective caesarean section/CS), Group III (emergency CS) and Group IV (induction of whelping). Doppler evaluations were conducted within one hour before whelping to assess blood flow measurements in the uteroplacental artery (UPA), umbilical artery (UMA), and fetal abdominal aorta (FAA) using pulsatility (PI) and resistance indices (RI). The mean PI and RI of UPA were 1.10 ± 0.06, 1.30 ± 0.09, 1.07 ± 0.06, and 1.07 ± 0.10, and 0.62 ± 0.02, 0.71 ± 0.02, 0.64 ± 0.02 and 0.66 ± 0.04 respectively, in Groups I, II, III and IV. The mean PI and RI of UMA were 1.26 ± 0.05, 1.39 ± 0.07, 1.23 ± 0.07 and 1.21± 0.11, and 0.67 ± 0.01, 0.73 ± 0.02, 0.70 ± 0.03 and 0.67 ± 0.03 respectively, in the aforesaid groups. The mean PI and RI of FAA were 1.36 ± 0.11, 1.55 ± 0.10, 1.55 ± 0.07 and 1.40 ± 0.16, and 0.73 ± 0.02, 0.72 ± 0.02, 0.75 ± 0.01 and 0.71 ± 0.03, respectively in the aforesaid groups. No significant difference ($p>0.05$) could be noticed in the mean PI and RI of different vessels between the groups on the day of parturition. Increased Doppler indices, especially in the UPA, close to whelping may result from reduced diastolic blood flow to the uterus due to uterine contractions.

Keywords: Doppler ultrasonography, Pulsatility index, Resistance index.

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INTRODUCTION

Trans-abdominal ultrasonography is a highly effective diagnostic technique for detecting pregnancy, assessing fetal growth, evaluating conceptus viability, accurately predicting delivery dates and determining post-whelping neonatal survival rates. It is also used in planned Caesarean sections (CS). Though conventional two-dimensional

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ultrasonography is used routinely to confirm canine pregnancy, foetal development, estimation of foetal age and demonstration of foetal growth retardation, it doesn't reveal the causes behind and provides less information regarding maternal and foetal blood flow (Bondestam *et al.,* 1983; England *et al.,* 1990). In human obstetrics, precise monitoring of the maternal and foetal blood flow patterns has contributed to the diagnosis and critical management of certain abnormal or pathological conditions (Robson, 2000). Elucidation of vascular information such as blood velocity, flow direction/pattern and vascular pathologies in real-time and thus predict abnormalities of pregnancy that start with minor changes in circulation are the major indications in canine obstetrics (Blanco *et al.,* 2010).

Hence, the Pulsed Wave (PW) Doppler ultrasound has become part of the routine reproductive evaluation in canines to aid in assessing perfusion and flow characteristics that provide important information regarding morphological and physiological aspects. Moreover, various pathogenic processes can also be differentiated through such hemodynamic changes thus augmenting the diagnosis and prognosis of the condition (Holen, 2014). However, minimal studies are available on Doppler predictors of normal and abnormal gestation (Arun *et al.,* 2016). Simon *et al.* (2021) demonstrated the use of colour Doppler ultrasound in managing pregnancy abnormalities, including foetal resorption and incomplete abortion. Pulsed Wave Doppler ultrasound is still a subject that requires further detailed studies in veterinary medicine. In bitches, it is primarily used to evaluate physiological aspects of the oestrous cycle, gestation and differentiation of uterine diseases. Meanwhile, it is used in male dogs to diagnose prostate and testicular disorders (Carvalho *et al.,* 2008; Nogueira *et al.,* 2017). Meanwhile, there are limited studies regarding Doppler evaluation during an impending parturition. A reduction in diastolic blood flow to the uterus caused by visible or occult uterine contractions during early labour was demonstrated in humans. This study attempts to evaluate any difference existing between the flow indices and aims to give way for further intra-partum Doppler evaluation and puppy survival prognosis for further obstetrical decision-making.

MATERIALS AND METHODS

Bitches that underwent vaginal birth (Group I, n=7), elective CS (Group II, n=8), emergency CS (Group III, n=7) and induced whelping using mifepristone (Group IV, n=6) presented to University Veterinary Hospitals, Kokkalai and Mannuthy constituted the material for the present study.

All 28 bitches were subjected to detailed echo biometric and Doppler evaluation during the hour preceding whelping. The Doppler ultrasonography was carried out with the MyLab Sigma (Esaote, Genoa, Italy) ultrasound machine in all the animals.

The bitches were placed in left lateral recumbency, and the hair on the ventral abdomen and the right flank was clipped with a hair trimmer. Acoustic coupling gel was applied to the transducer and onto the skin. The colour Doppler was utilized to visualise the vessels, followed by the use of the PW Doppler to measure the blood flow parameters, including the pulsatility index (PI) and resistance index (RI). The baseline and gate size were adjusted as needed to achieve consistent consecutive waveforms. The PW Doppler mode was activated by maintaining the transducer's position and precisely adjusting the gate size within the blood flow. Three consecutive waves with similar velocity and amplitude systolic peaks were then captured and recorded for further analysis.

The UPA was located in the neighbourhood of the gestational sac or between two gestational sacs. The umbilical artery waveforms were recorded at the mid-cord site of the free-floating cord and the abdominal aorta was identified and located at the aortic arch (Di Salvo *et al.,* 2006; Simon, 2015).

Analysis of the waveforms

The waveforms of various vessels included in the study were manually traced and measured using the velocity trace option. For each recording, the following values were automatically calculated by the ultrasound scanner software in the flow velocity index (FVI) mode. The following formulae were used to calculate the flow indices.

Pulsatility Index (PI) (Gosling's Index)

PI = (S – D)/Vm
S = peak systolic velocity
D= end-diastolic velocity
Vm = time-averaged maximum velocity over the cardiac cycle

Resistive Index (RI)(Pourcelot's Index or Resistance Index)

RI = (S – D)/S

Statistical Analysis

Statistical analysis of the collected data was performed on SPSS version 24.0. One-way ANOVA followed by Duncan's

multiple range test was done to compare parameters between the four groups.

RESULTS AND DISCUSSION

Doppler haemodynamic indices of uteroplacental artery (UPA)

Normal circulation is essential for providing the fetus with adequate oxygen and nutrients, which is crucial for physiological development (Nautrup, 1998). A greater blood flow to the placenta fulfilled this increased demand. Osol and Mandala (2009) opined that in humans, remodelling of the maternal uterine vasculature during gestation is a distinctive cardiovascular process. The extent of this increase in uteroplacental blood flow varied depending on the species, ranging from 10 to 100 times the levels observed in non-pregnant states.

In the current study, there was a complete disappearance of the early-diastolic notch (EDN) from UPA of all the animals during the late gestation (Fig. 1 and Fig. 2). All the bitches showed invariably a biphasic pattern of waveform for UPA. The observations were in close correspondence with Simon *et al.* (2021), who observed a biphasic waveform pattern throughout the study and a total disappearance of EDN of UPA from 41-50 days of pregnancy. Similarly, George (2012) also observed the complete disappearance of the early diastolic notch of the UPA from 41 - 50 d of gestation.

The Doppler hemodynamic indices of UPA in different groups are presented in Table 1. The mean PI within one hour of whelping was 1.10 ± 0.06, 1.30 ± 0.09, 1.07 ± 0.06 and 1.07 ± 0.10 in Groups I, II, III and IV, respectively. The mean RI within one hour before whelping was 0.62 ± 0.02, 0.71 ± 0.02, 0.64 ± 0.02 and 0.66 ± 0.04 in Groups I, II, III and IV, respectively. No significant difference ($p>0.05$) could be noted in mean PI and RI between the groups on the day of parturition.

By periodic evaluation of UPA at ten-day intervals (< 30 d, 31-40 d, 41-50 d and > 50 d), Simon *et al.* (2021) showed that the PI and RI decreased significantly throughout the study and the observed mean PI and RI values at late gestation were 0.631 ±0.022 and 0.44 ±0.012 respectively. These findings were supported by the findings of Di Salvo *et al.* (2006), George (2012) and Freitas *et al.* (2016).

However, the present study showed relatively higher Doppler values regardless of the groups of observation, possibly due to the difference in the time at which the measurements were taken. Moreover, increased Doppler indices values obtained close to whelping, irrespective of the groups in the present study, might be the reflection of a reduction in diastolic blood flow to the uterus caused by occult or visible uterine contractions during the parturition. This was supported by a study in humans by Cooley *et al.* (2011), who opined the existence of an obvious correlation between the reduction of diastolic blood flow and uterine contraction.

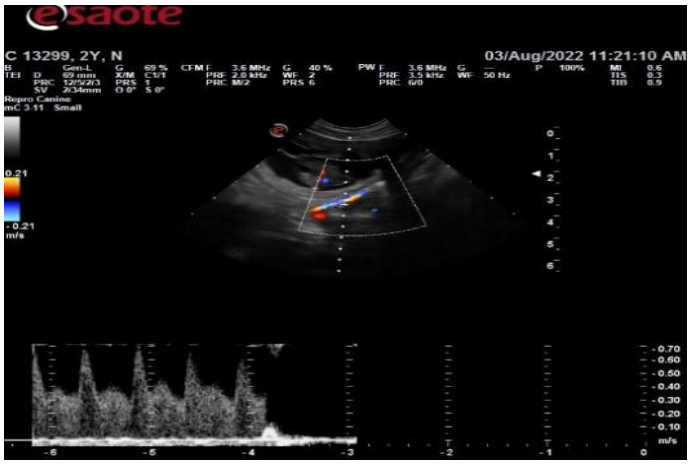

Fig. 1. Pulsed wave Doppler sonogram of Uteroplacental artery showing end diastolic notch at early gestation

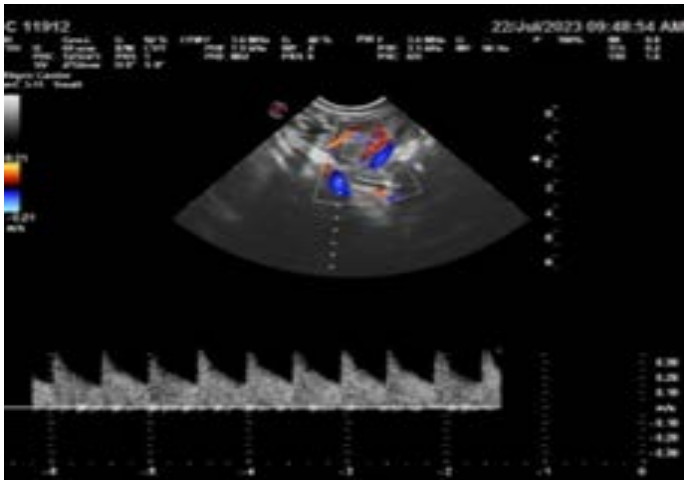

Fig. 2. Pulsed wave Doppler sonogram of UPA showing complete disappearance of EDN on the day of parturition

Table 1. Resistance index (RI) and pulsatility index (PI) (Mean±SE) of UPA on the day of parturition in different groups of bitches (n=28)

Doppler indices	Group I	Group II	Group III	Group IV	F-value (P-value)
PI	1.10 ± 0.06	1.30 ± 0.09	1.07 ± 0.06	1.07 ± 0.10	2.037^{ns} (0.136)
RI	0.62 ± 0.02	0.71 ± 0.02	0.64 ± 0.02	0.66 ± 0.04	2.045^{ns} (0.134)

ns non-significant

Doppler haemodynamic indices of umbilical artery (UMA)

The Doppler waveforms and hemodynamic indices of UMA in different groups are presented in Fig. 3 and Table 1. In the present study, all the bitches showed invariably a biphasic pattern of waveform for UMA. The observations were in close correspondence with Simon *et al.* (2021), who observed a biphasic waveform pattern from day 41 of pregnancy.

The mean PI during the hour preceding whelping was 1.26 ± 0.05, 1.39 ± 0.07, 1.23 ± 0.07 and 1.21± 0.11 in Groups I, II, III and IV, respectively. The mean RI during the hour preceding whelping was 0.67 ± 0.01, 0.73 ± 0.02, 0.70 ± 0.03 and 0.67 ± 0.03 in Groups I, II, III and IV, respectively. No significant difference (p>0.05) could be noticed in mean PI and RI between the groups on the day of parturition.

Similar findings were noted by Simon *et al.* (2021) who obtained a mean umbilical artery PI and RI values of 1.441 ±0.03 and 0.73 ±0.011, respectively during> 50 d (51-60 d) of gestation. The aforementioned PI and RI values of UMA during the progress of pregnancy were congruent with observations of Di Salvo *et al.* (2006), Miranda and Domingues (2010), Blanco *et al.* (2010), George (2012) and Freitas *et al.* (2016).

The observations were in alignment with Giannico *et al.* (2016) who reported that the RI of the UMA declined during the periods 12–6 and 6–1 h before delivery, with the lowest values obtained of less than or equal to 0.7.

Doppler haemodynamic indices of foetal abdominal aorta (FAA)

The Doppler waveforms and hemodynamic indices of FAA in different groups are presented in Fig.4 and Table 3. In the present study, all the bitches showed invariably a biphasic pattern of waveform for FAA. The observations were in close correspondence with Simon *et al.* (2021), who observed a biphasic waveform pattern during the later stages of gestation. The observation that FAA shows biphasic waveform during later gestation was in also congruence with Nautrup (1998), Di Salvo *et al.* (2006) and George (2012).

The mean PI during the hour preceding whelping was 1.36 ± 0.11, 1.55 ± 0.10, 1.55 ± 0.07 and 1.40 ± 0.16 in Groups I, II, III and IV, respectively. The mean RI during the hour preceding whelping was 0.73 ± 0.02, 0.72 ± 0.02, 0.75 ± 0.01 and 0.71 ± 0.03 in Groups I, II, III and IV respectively. No significant difference (p>0.05) could be noticed in mean PI and RI between the groups on the day of parturition.

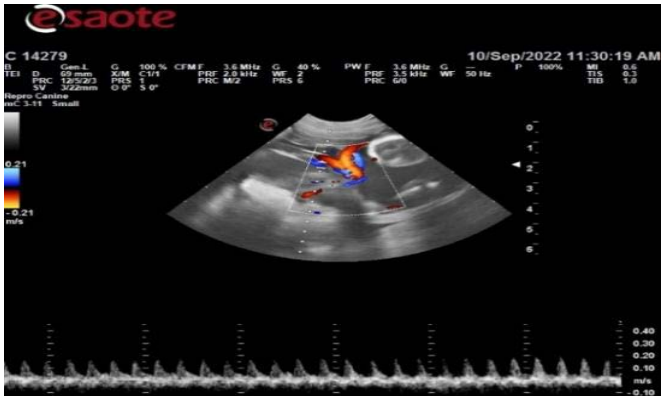

Fig. 3. Pulsed wave ultrasonogram of the umbilical artery (above baseline) showing biphasic waveforms and wavy umbilical venous flow below baseline on the day of parturition

Table 2. Resistance index (RI) and pulsatility index (PI) (Mean±SE) of UMA on the day of parturition in different groups of bitches (n=28)

Doppler indices	Group I	Group II	Group III	Group IV	F-value (P-value)
PI	1.26 ± 0.05	1.39 ± 0.07	1.23 ± 0.07	1.21 ± 0.11	1.127^{ns} (0.358)
RI	0.67 ± 0.01	0.73 ± 0.02	0.70 ± 0.03	0.67 ± 0.03	1.618^{ns} (0.211)

ns non-significant

The observed PI and RI values in the present study were in alignment with Simon *et al.* (2021), who obtained a mean foetal abdominal aorta PI and RI value of 1.476 ± 0.055 and 0.707 ± 0.021, respectively in late gestation.

Comparatively increased Doppler indices values obtained during the hour preceding whelping in the present study particularly that of UPA might be due to a reduction in diastolic blood flow to the uterus caused by uterine contractions.

Table 3. Resistance index (RI) and pulsatility index (PI) (Mean±SE) of FAA on the day of parturition in different groups of bitches (n=28)

Doppler indices	Group I	Group II	Group III	Group IV	F-value(P-value)
PI	1.36 ± 0.11	1.55 ± 0.10	1.55 ± 0.07	1.40 ± 0.16	0.842^{ns} (0.484)
RI	0.73 ± 0.02	0.72 ± 0.02	0.75 ± 0.01	0.71 ± 0.03	0.525^{ns} (0.669)

ns non-significant

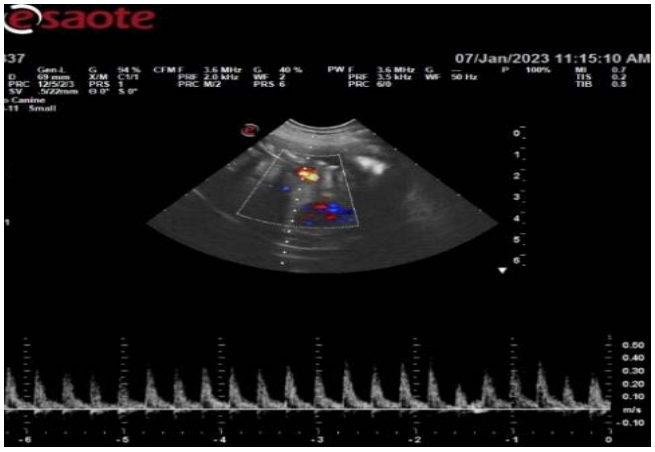

Fig. 4. Pulsed wave Doppler sonogram of foetal aorta showing biphasic forms on the day of parturition

CONCLUSION

Pulsed Wave Doppler analysis of blood flow of both maternal and foetal vessels is a highly rewarding technique for monitoring pregnancy in dogs. The different maternal and foetal vessels *viz.,* UPA, UMA and FAA have implications on assessing pregnancy progress and outcome. The higher Doppler indices obtained for UPA during the hour preceding whelping are a matter of future research. Moreover, there are only limited studies about the assessment of the mechanism of foeto-placental exchange and foetal adaptive systems just before whelping and intrapartum to compare with. More detailed studies regarding abnormal pregnancies are required to obtain critical values of flow parameters in such clinical situations.

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CONFLICT OF INTEREST

The authors don't have any conflict of interest.

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