RESEARCH ARTICLE

Assessment of Uterine and Umbilical Artery Haemodynamics at Different Stages of Gestation in Goats

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Abstract

Doppler indices of the uterine and umbilical arteries are valuable for assessing foetal viability and intrauterine growth. This study evaluated blood flow in the umbilical (UmA) and uterine arteries (UtA) during first (<50 days), second (51-100 days) and third (>101 days) stage/trimesters of gestation in Attappady Black (low prolific) and Malabari (high prolific) goats. Six does per breed were assessed in each stage for Resistance Index (RI) and Pulsatility Index (PI). Both UmA and UtA indices showed a significant decline ($p \leq 0.05$) as gestation progressed. UmA PI and RI significantly decreased in third stage compared to first and second stage in both breeds; though no interbreed differences were noted. In Malabari goats, the left UtA showed significant reductions from the first to third stage (PI: 1.08 ± 0.08 to 0.80 ± 0.08; RI: 0.83 ± 0.06 to 0.63 ± 0.05), while in Attappady goats, the right UtA showed similar changes from second to third stage (PI: 1.13 ± 0.09 to 0.83 ± 0.09; RI: 0.74 ± 0.02 to 0.62 ± 0.02). No significant variation was observed in the left UtA of Attappady or the right UtA of Malabari goats. These findings highlight gestational haemodynamic changes and provide reference Doppler values for evaluating uteroplacental circulation in goats.

Key words: Doppler indices, Malabari and Attappady goats, Pregnancy, Umbilical artery, Uterine artery.

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Introduction

Malabari and Attappady black goats are prominent breeds of Kerala, a state in southern India. Malabari is a highly prolific breed with 50 % twinning, 25 % triplets and 5 % quadruplets (Verma *et al*., 2009), while Attappady Black is a low prolific breed with smaller litter size often with single births than twinning and triplets. The use of colour and pulsed Doppler during pregnancy offers qualitative and quantitative vascular information about the haemodynamic characteristics of the dam and foetus, including venous or arterial blood type, circulation and velocity. These data have significant clinical implications for gynaecological disorders in both human and animal species. According to Giannico *et al*. (2015), the assessment of resistance, pulsatility, systolic and diastolic velocities and blood flow volume determines the measured vascular perfusion. Doppler ultrasound analysis and Doppler parameters in goat pregnancies with complications remain largely unexplored due to insufficient research.

Foetal health, development and cardiac function are often assessed using the pulsations of the umbilical artery (UmA). The umbilical vessels play a vital role in foetal metabolism by transporting deoxygenated blood and waste products from the foetus and delivering oxygenated blood and nutrients from the dam through the umbilical veins. Studies have shown that the vascular system within the umbilical cord undergoes adaptive changes to accommodate haemodynamic demands and maintain adequate blood flow to the growing placenta and foetus. A marked shift in UmA Doppler indices has been reported around middle of the second trimester, indicating a critical stage in caprine gestation (Serin *et al*., 2010). Despite its diagnostic value, the accuracy of UmA Doppler waveform analysis may be affected by small vessel size and technical limitations.

The uterine artery (UtA), on the other hand, demonstrates significant reductions in resistance index (RI) and systolic/diastolic (S/D) ratio as pregnancy progresses, along with changes in pulsatility index (PI). These variations reflect alterations in vascular tone and luminal diameter to support increased uteroplacental perfusion. The RI and PI, influenced by maternal heart rate and blood flow, serve as essential indicators of uteroplacental health and foetal well-being. Elevated maternal stress levels have been linked to increased

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uterine RI, which may contribute to intrauterine growth restriction and low birth weight. Additionally, UtA Doppler assessments can aid in predicting the parturition, diagnosing maternal conditions such as uterine torsion, metritis and retained placenta and identifying the risk of dystocia.

Monitoring uterine and umbilical artery Doppler indices at various stages of gestation in indigenous goat breeds provides critical insights into maternal–foetal haemodynamics. It also aids in detecting early signs of gestational complications and breed-specific vascular adaptations. Thus, the present study aimed to establish reference values for the haemodynamic characteristics of the uterine and umbilical arteries during gestation in Malabari and Attappady goats, as there is limited research available for these indigenous breeds.

Materials and Methods

The study was conducted in Goat and Sheep Farm, College of Veterinary and Animal Sciences, Mannuthy, Thrissur, KAVASU, India. The goats were maintained under semi-intensive housing system with identical conditions of feeding and management. The does were regularly dewormed, vaccinated and ear tagged for proper identification. A total of 36 goats of age group 2-5 years were used in the study, comprising 18 Malabari and 18 Attappady goats. These animals were grouped based on the stage of pregnancy into three categories: first stage (less than 50 days), second stage (51-100 days) and third stage (more than 101 days) of gestation, with six animals from each breed in each stage. The day of natural mating was considered as day 0 of pregnancy. Ultrasound examinations were conducted using a MyLab Sigma Scanner (Esaote, Italy) equipped with a trans-rectal (TR) linear array and a trans-abdominal (TA) micro-convex probe, operating at a frequency of 5-10 MHz. Pregnancy was confirmed using both TR and TA transducers. Doppler indices (pulsatility index and resistance index), of UmA and UtA were recorded using two-dimensional ultrasound combined with colour and pulse-wave Doppler imaging. During TR ultrasonographic examinations, the does were restrained in standing position and the rectum was evacuated. The probe was protected by a latex glove infused with sufficient gel and lubricated before insertion. The uterine artery was identified transrectally, lateral and cranial to urinary bladder, near to the external iliac artery. To achieve this, probe was directed to dorsal aspect of rectum, towards abdominal aorta, a further 90^{o} rotation to either side identified the middle uterine arteries on both sides. The umbilical artery was located as freely floating cord between conceptus and gestational sac (Fig. 1a,1b). Pulsed-wave Doppler ultrasonography was used after the Colour-Doppler application to visualize the arteries. Measurements were taken for both Attappady and Malabari pregnancies and the data were statistically analyzed (Snedecor and Cochran, 1994) using software program IBM SPSS statistic (version 24.0), to assess variations across gestational stages.

Results and Discussion

Litter size was recorded immediately after kidding in both the breeds. In Attappady goats, the percent of single, twin and multiple pregnancies were 88.88, 11.11, and 0, respectively, whereas in Malabari goats, the values were 0, 11.11 and 88.8 %, respectively.

Pulsatility Index (PI) and Resistivity Index (RI) of Umbilical Artery

The mean PI and RI values of UmA in Attappady goats from first to third stage of gestation were 1.18±0.07 to 0.79±0.07 and 0.78±0.01 to 0.64±0.01, respectively, and in Malabari goats 1.29±0.07 to 0.82±0.07 and 0.82±0.01 to 0.68±0.01, respectively. The mean PI and RI values did not show any significant difference between the breeds in any of the stages of gestation. A significantly lower PI and RI values were observed in the third stage of pregnancies in both the breeds compared to first and second stages, consistent with increased umbilical blood flow due to rapid foetal growth during the terminal stage of pregnancy (Table 1). When breed wise interpretation across stages of pregnancy was done, significant differences ($p<0.05$) were identified in the low prolific Attappady breed pregnancies across different gestational stages for both PI and RI, with the highest values recorded during the second stage, which was notably distinct from those in the first and third stages. In contrast, the high prolific Malabari breed pregnancies exhibited no significant variations across the different stages, implying a more stable Doppler profile throughout their gestation. Notably, the low prolific breed pregnancies goats exhibited more significant fluctuations, with values reaching a peak in the second trimester before declining, suggesting a dynamic adaptation of the vascular system.

In contrast, Malabari goats demonstrated more stable resistance levels, which may indicate a more consistent placental perfusion throughout the gestational period. Serin *et al*. (2010) reported that PI and RI dropped by 85 days of gestation in Saanen goats and the UmA pulsatility and resistivity of the foetuses observed did not differ significantly between singleton and multiple pregnancies. It has been noted that haemodynamic indices reached a threshold around the middle of the second stage in caprine pregnancy. Kumar *et al*. (2015) observed a significant elevation of PI between 42 and 48 days of gestation in Beetal goats, which dramatically dropped between 98 and 105 days of gestation. There was no discernible increase or reduction on the other days. Since the RI value did not significantly increase or decrease, it was more stable than the PI values. The Doppler index values of the umbilical artery observed in this study differed from those reported in other breeds, which might be attributed to breed specific variations in placental

development, vascular architecture and haemodynamic adaptations during gestation. However, the values obtained in this study may serve as reference standards for monitoring pregnancy in Attappady and Malabari goats.

Pulsatility Index (PI) and Resistivity Index (RI) of Uterine Artery

On examination of Doppler indices of left UtA, Attappady goats exhibited no significant variations in PI or RI throughout the three gestational stages. Conversely, Malabari goats demonstrated a notable decline in PI from the first stage to the third stage, decreasing from 1.08 to 0.80, with the first stage presenting significantly higher values. Although RI showed a decreasing trend in Malabari goats, the significant difference ($p \leq 0.05$) was observed only between the first and third stage of gestation. Regarding the right UtA, Attappady goats displayed the highest PI during the second stage at 1.13, which was significantly different from the values recorded in the first and third stages. RI also showed a slight increase in the second stage, indicating a rise in resistance during mid-gestation. In contrast, Malabari goats did not exhibit significant differences in either PI or RI across the various stages of gestation. The mean values of PI and RI in left and right UtA did not differ significantly between the breeds in any of the stages of pregnancy (Table 2). Beltrame *et al*. (2017) and Madhusudhan (2019) found no significant change in left and right UtA PI and RI mean values between singleton and multiple foetal gestations in Santa Ines ewes and in Malabari goats, respectively.

The uterine artery PI and RI values were higher during the first two stages of gestation and showed a decline in the third stage, reflecting increased foetal blood flow as gestation progressed. Similar observations were reported in mixed breeds of sheep and goats by Erdogan (2012), Elmetwally (2012, 2016) and Beltrame *et al*. (2017). While consistent differences between the left and right uterine arteries were absent, some asymmetrical trends were noted, particularly a significant decrease in right sided resistance from second to third stage of gestation in Attappady goats, suggestive of more frequent pregnancies occurring in the right uterine horn in this breed. While such significant reduction in PI and RI values was observed in the left UtA in Malabari breed. In this study although Malabari had higher incidence of multiple pregnancies such variation in the Doppler indices could not be observed between the two breeds. These observations are consistent with the findings of Beltrame *et al*. (2017) and Madhusudhan (2019). According to Del Aguila-Silva *et al*. (2021), the mean values of PI and RI variables were correlated with the number of foetuses per pregnancy, indicating that the values of these variables will be lower when the pregnancy is multiple. According to Panarace *et al*. (2006), during the early and later phases of pregnancy, there was a notable reduction in the uterine artery resistance index and S/D ratio. As the pregnancy progressed, there was significant variation in uterine artery PI at each of the three phases in Aberdeen Angus cow. This alteration was ascribed to the distal vascular bed's ongoing development as well as modifications to the uterine vessels tone and diameter. However, small vessel size or transducer distance can occasionally impair the accuracy of Doppler measurements (Schmidt *et al*., 1991). Anxiety or stress on the part of the dam during pregnancy raised the uterine vascular RI, which was linked to low birth weight and delayed foetal growth (Teixeira *et al*., 1999).

Conclusion

As gestation progressed, a significant decline in the mean pulsatility index (PI) and resistance index (RI) of both the UmA and uterine UtA were observed during the third stage of pregnancy in Attappady and Malabari goats, reflecting improved uterine and placental blood flow in late gestation. While no significant overall differences were found between the two breeds in UmA and UtA indices, however, notable side-specific variations emerged. In Attappady goats, the right

Table 1: Comparison of PI and RI values of umbilical artery in Attappady and Malabari does at different stages of pregnancy

Stage of pregnancy	PI		RI	
	Attappady	Malabari	Attappady	Malabari
First	1.18 ± 0.07^{Ab}	1.29 ± 0.07^{Ab}	0.78 ± 0.01^{Ab}	0.82 ± 0.01^{Ab}
Second	1.44 ± 0.07^{Ac}	1.31 ± 0.07^{Ab}	0.87 ± 0.01^{Ac}	0.84 ± 0.01^{Ab}
Third	0.79 ± 0.07^{Aa}	0.82 ± 0.07^{Aa}	0.64 ± 0.01^{Aa}	0.68 ± 0.01^{Aa}

Different superscripts in lower case indicate significant difference between the stages and superscripts in uppercase indicate significant different between the breeds at 5% level

Table 2: Comparison of PI and RI values of uterine artery in Attappady and Malabari does in different stages of pregnancy

Stage of pregnancy	LT UtA PI		LT UtA RI		RT UtA PI		RT UtA RI	
	Attappady	Malabari	Attappady	Malabari	Attappady	Malabari	Attappady	Malabari
First	0.91 ± 0.08^{Aa}	1.08 ± 0.08^{Ab}	0.64 ± 0.05^{Aa}	0.83 ± 0.05^{Ab}	0.85 ± 0.09^{Aa}	1.07 ± 0.09^{Aa}	0.63 ± 0.0^{Aa}	0.67 ± 0.02^{Aa}
Second	1.09 ± 0.08^{Aa}	0.88 ± 0.08^{Aa}	0.69 ± 0.05^{Aa}	0.71 ± 0.05^{Aab}	1.13 ± 0.09^{Ab}	1.08 ± 0.09^{Aa}	0.74 ± 0.02^{Ab}	0.67 ± 0.02^{Aa}
Third	0.91 ± 0.08^{Aa}	0.80 ± 0.08^{Aa}	0.65 ± 0.05^{Aa}	0.63 ± 0.05^{Aa}	0.83 ± 0.09^{Aa}	0.92 ± 0.09^{Aa}	0.62 ± 0.02^{Aa}	0.66 ± 0.02^{Aa}

Different superscripts in lower case indicate significant difference between the stages and superscripts in uppercase indicate significant different between the breeds at 5% level

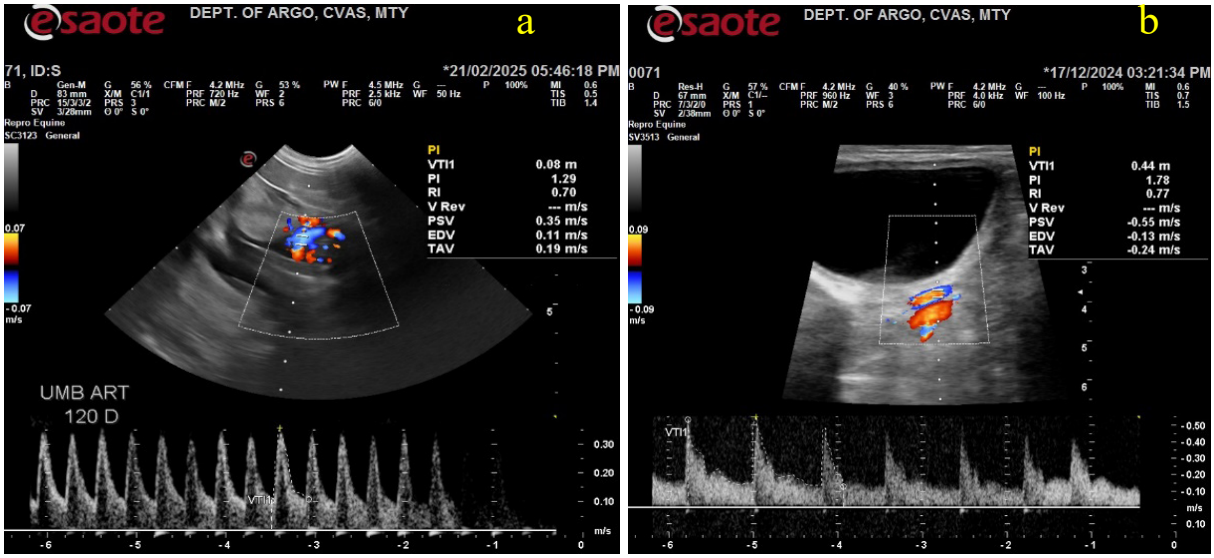

Fig 1a, b: Doppler indices of umbilical and uterine artery in goats

UtA showed significant changes, whereas in Malabari goats, significant differences were noted in the left UtA. The results indicated that uterine artery Doppler indices varied between the left and right sides, influenced by the common site of pregnancy in each breed. In Attappady goats, pregnancies were mostly confined to the right uterine horn, whereas in Malabari goats, both uterine horns were typically occupied. These differences may reflect physiological adjustments in uterine blood flow according to the litter size typical of each breed. The reference Doppler values established in this study may serve as a baseline for these native goat breeds, though further research with larger populations is needed to fully characterize uterine blood flow patterns and distinguish physiological from pathological changes during pregnancy.

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