Indian Journal of Animal Sciences **89**(5): 491–494, May 2019/Article
https://doi.org/10.56093/ijans.v89i5.90011

Doppler indices of middle uterine artery as a tool for predicting the fetal status in cattle with uterine torsion and the recovery of uterine blood flow subsequent to detorsion

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ABSTRACT

The aim was assessment of blood flow to uterus in cattle suffering from uterine torsion as a tool for predicting the fetal survivability after detorsion. Dairy cattle (14) with uterine torsion were detorted and fetal delivery was completed within 30 min after detorsion. Doppler sonography of middle uterine artery ipsilateral (IpsiUA) and contralateral (ContUA) to the side of torsion was carried out before uterine detorsion and 30 min after fetal delivery for Doppler indices, viz. blood flow volume (BFV), time-averaged peak velocity (TAP), resistance index (RI) and pulsatility index (PI). Before uterine detorsion, RI-IpsiUA and PI-IpsiUA were high in comparison to their values in ContUA. Although RI-IpsiUA and PI-IpsiUA had difference between their values before uterine detorsion and 30 min after fetal delivery, but in contrast, at the same time point, there was no difference in RI-ContUA and PI-ContUA. In comparison to RI-IpsiUA and PI-IpsiUA before detorsion, their respective values decreased after fetal delivery subsequent to successful detorsion, and were almost similar to their respective post-fetal delivery RI-ContUA and PI-ContUA. In cases where fetus after detorsion of uterus was delivered dead, in the middle uterine artery ipsilateral to the side of uterine torsion, BFV-IpsiUA and TAP-IpsiUA were low, whereas PI-IpsiUA were high. In conclusion, depicting the blood flow within middle uterine artery using Doppler sonography could be helpful in predicting the viability of fetus in uterine torsion affected cattle and may confirm the resumption of blood flow to uterus subsequent to detorsion.

Key words: Cattle, Doppler sonography, Spectral waveform, Uterine artery, Uterine torsion

In pregnant bovines, the middle uterine artery and vein are compressed following uterine torsion, thus leading to an increase in blood carbon dioxide and associated decrease in oxygen in fetal blood. Consequently, due to asphyxia, the fetus tends to struggle and further aggravates the condition by increasing the degree of torsion, necrosis of uterine tissue, endotoxemia and ultimately death of fetus and/or dam (Ghuman 2010). Transrectal colour Doppler sonography can be used to investigate uterine blood flow in cattle (Panarace *et al*. 2006), buffalo (Varughese *et al*. 2013) and mare (Bollwein *et al.* 2004). In humans, blood flow of placental circulation in normal pregnancy was helpful in diagnosing the retardation in fetal growth, ovarian torsion and various peri-partum diseases (Bewley *et al.* 1991, Shadinger *et al.* 2008). In bovines affected with uterine torsion, Doppler sonography of uterine artery can be useful for the categorization of their prognostic status (Schönfelder *et al.* 2005, Hussein 2013). The impact of uterine torsion on fetus and dam can be reduced with timely diagnosis and appropriate treatment based on the Doppler aided information. Thus, the present study on uterine torsion affected cattles was designed to investigate the interference in uterine blood flow in relation to fetal status and the recovery of uterine blood flow subsequent to detorsion using Doppler sonography technique.

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MATERIALS AND METHODS

Animals and clinical examination: Fourteen multiparous dairy cattle with complete gestation period were presented at Referral Veterinary Hospital of the University with the history of abdominal pain and restlessness for the past 24–72 h. Individual animal case history was recorded and general condition of animal was assessed through clinical examinations. A careful vaginal and rectal examination diagnosed degree (≤180º, n=6; >180º, n=8) and direction (clockwise or right side, n=12; counter-clockwise or left side, n=2) of uterine torsion, as well as the vaginal involvement (pre-cervical, n=0; post-cervical, n=14).

Detorsion of uterus and fetal delivery: Uterine torsion in the pregnant cattle was removed as per Sharma's modified Schaffer's method (Ghuman 2010). During detorsion of uterus, a single roll was sufficient for five cattle and nine cattle were subjected to two rolls. Per-vaginal delivery of live (n=6) or dead (n=8) fetus was completed subsequent

to complete cervical dilatation with the help of obstetrical procedures, if required. In all the fetal delivery occurred within 30 min after successful detorsion of uterus.

Doppler sonography of uterine blood flow: A portable colour Doppler ultrasound system (M-Turbo, SonoSite Inc., Bothell, USA) equipped with a 5.0–7.5 MHz linear transducer was used for measuring Doppler indices through transrectal approach. About 30 min after the presentation of uterine torsion affected cattle at hospital and about 30 min after per-vaginal delivery of fetus subsequent to detorsion, the medial uterine artery ipsilateral (IpsiUA) and contralateral (ContUA) to uterine torsion was examined for measuring Doppler indices (Bollwein *et al*. 2000, Herzog and Bollwein 2007). In brief, the uterine artery was recognized within the mesometrium near to its origin at the rudimentary umbilical artery and close to the external iliac artery. At this location, middle uterine artery blood flow waveforms and values of various Doppler indices were obtained using pulsed Doppler mode by placing the Doppler gate over the uterine artery adjusted to the diameter of artery (Fig. 1).

Doppler indices: Various Doppler indices like pulsatility index (PI), resistance index (RI), time-average peak velocity over the cardiac cycle (TAP), and blood flow volume flow (BFV) are useful for estimating the blood flow resistance in vessels distal to the point of examination (Dickey 1997). To increase accuracy of the Doppler indices, at least 3–4 cardiac cycle wave forms were used (Figs 2 and 3) and at least three measurements were taken for each parameter. Resistance index (RI = Peak systolic volume (PSV) - End diastolic volume (EDV) / PSV) relates to negative relation with vascular perfusion and decreasing resistance increases

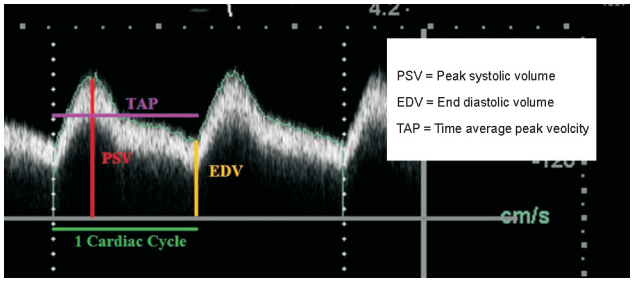

Fig. 2. Sonograph image showing spectral waveform (a cardiac cycle) of middle uterine artery.

vascular perfusion and vice versa (Elmetwally 2012). Pulsatility index (PI = PSV - EDV / Time-averaged Peak velocity, TAP) relates to negative relation with vascular perfusion and increasing PI indicates constriction of vascular bed distal to the site of measurement, decreased tissue perfusion and vice versa (Elmetwally 2012). Time-averaged peak velocity (TAP, cm/s = Time averaged maximum frequency shift over the cardiac cycle (TAMF) × ultrasound propagation speed, (c / 2) × Transmitted wave frequency, ($F \times \cos\text{-}\alpha$), where α is the angle between ultrasound beam and blood flow direction) is used to evaluate the blood flow in small vessels (Bollwein *et al.* 2002). Blood flow volume (BFV, ml/min = [TAP × π × artery diameter, *D*, $\text{cm} \times 0.5]^2 \times 60$) to the target tissue depends on the mean velocity and diameter of target blood vessel (Krueger *et al*. 2009).

Statistical analysis: Data (mean±SEM) was analyzed using IBM SPSS version 21. One way analysis of variance was used to compare the values of Doppler indices before detorsion and after delivery of fetus. Retrospective analysis

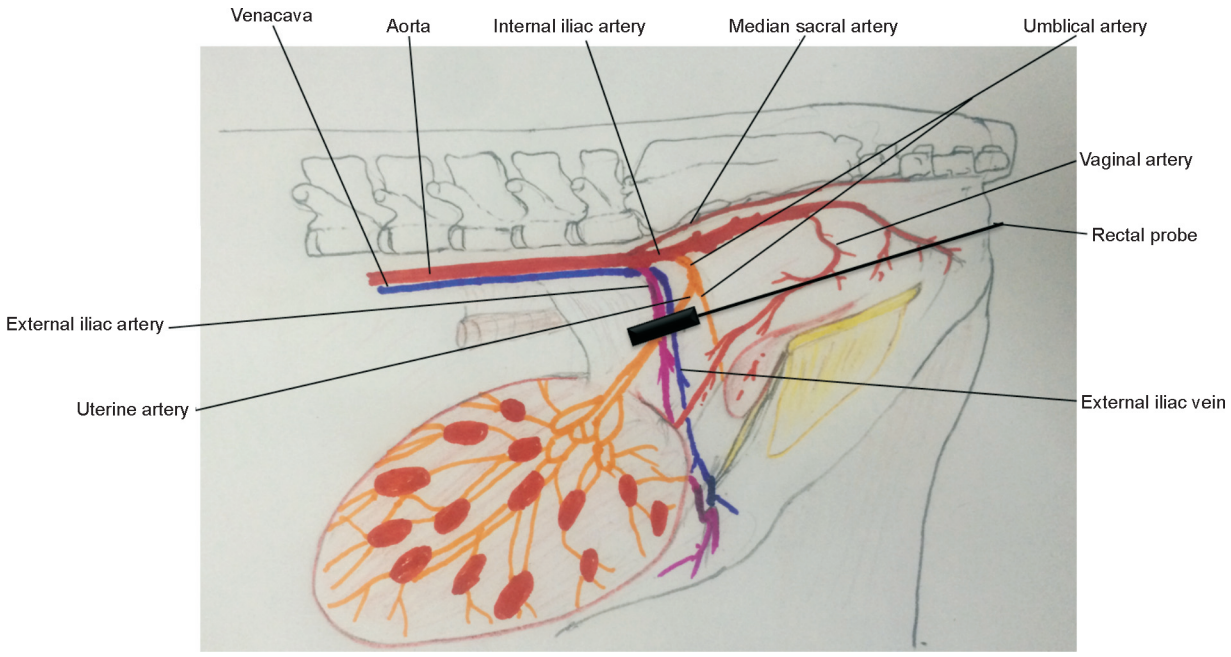

Fig. 1. Diagrammatic representation of middle uterine artery showing location for the placement of sonography probe through transrectal approach.

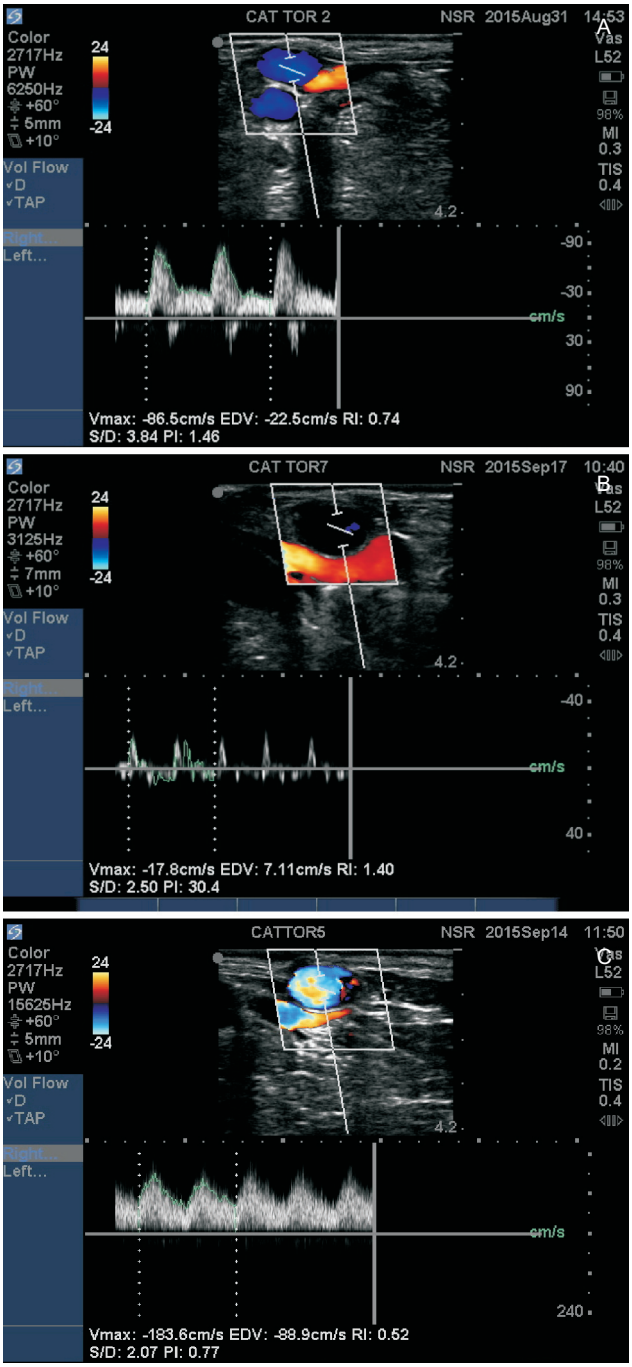

Fig. 3. Sonograph image showing waveform of middle uterine artery in cattle with uterine torsion. **A**. Spectral waveform of middle uterine artery (MUA) before detorsion of uterus in a cattle bearing live fetus confirming the hindrance of blood flow through the vessel as indicated by resistance and pulsatility index (RI, PI). Blue colour filled in cross-section of MUA is indicative of blood flow. **B**. Spectral waveform of middle uterine artery (MUA) before detorsion of uterus in a cattle bearing dead fetus showing higher resistance and pulsatility index (RI, PI) due to greater impedance in vessel which further confirms the severity of condition. Decrease in blue colour in cross-section of MUA is indicative of poor blood flow. **C**. Spectral waveform of middle uterine artery (MUA) ~30 min after delivery of fetus showing decrease in resistance and pulsatility index (RI, PI) as a result of removal in obstruction to blood flow. Yellowish blue colour in cross-section of MUA is indicative of higher blood flow.

of data of Doppler indices before uterine detorsion was also carried out to assess the chances of survivability of fetus. The differences with P<0.05 were considered statistically significant.

RESULTS AND DISCUSSION

A well-defined literature exists suggesting the role of duration and degree of occurrence of uterine torsion while deciding about the survival prognosis of unborn calf and dam as well as the future reproductive health of dam (Ghuman 2010). However, in certain circumstances, the history about the occurrence of uterine torsion is not reliable or appropriate. In order to establish another prognostic tool for obstetricians, the present pioneer study suggested that Doppler sonography of middle uterine artery can be used as a tool for predicting the survivability of fetus in cattle suffering from uterine torsion as well as investigated the restart of blood flow to uterus subsequent to successful detorsion and delivery of fetus.

Before starting the process of uterine detorsion, both resistive index (RI-IpsiUA) and pulsatility index (PI-IpsiUA) were high in the middle uterine artery ipsilateral to the side of uterine torsion in comparison to their values in contralateral uterine artery (RI-ContUA, PI-ContUA; P<0.05, Table 1). Furthermore, although RI-IpsiUA and PI-IpsiUA had difference (P<0.05) between values before detorsion and 30 min after fetal delivery, but at the same time points there was no difference (P>0.05) in values of RI-ContUA and PI-ContUA (Table 1). This is due to the fact that middle uterine artery ipsilateral to the side of uterine torsion is severely compressed. Thus, the impedance

Table 1. Doppler indices (mean±SEM) of middle uterine artery in cattle (n=14) presented with uterine torsion and delivering live or dead fetus subsequent to uterine detorsion

Doppler index	Before detorsion (n=14)	30 min after fetal delivery (n=14)	Live fetus (n=6)	Dead fetus (n=8)
BFV-IpsiUA (ml/min)	1468± 226[a]	2774± 257[b]	2232± 329[e]	822± 197[f]
BFV-ContUA (ml/min)	1841± 165	2314± 201	2381± 215[e]	1343± 151[f]
TAP-IpsiUA (cm/s)	46.8± 8.4	79.6± 9.6	73.9± 11[e]	25.5± 8.5[f]
TAP-ContUA (cm/s)	58.88± 5.85[a]	86.2± 10.85[b]	78.6± 8.08[e]	40.67± 4.33[f]
RI-IpsiUA (Index)	0.70± 0.04[a,c]	0.57± 0.02[b]	0.63± 0.04	0.76± 0.06
RI-ContUA (Index)	0.60± 002[d]	0.58± 0.03	0.60± 0.04	0.60± 0.03
PI-IpsiUA (Index)	1.79± 0.28[a,c]	0.96± 0.07[b]	1.1± 0.1[e]	2.5± 0.5[f]
PI-ContUA (Index)	1.03± 0.07[d]	1.02± 0.06	1.06± 0.13	1.00± 0.07

[a,b,c,d,e,f]P<0.05. BFV, blood flow volume; TAP, time averaged peak velocity; RI, resistive index; PI, pulsatility index; IpsiUA, ipsilateral and ContUA, contralateral middle uterine artery.

to blood flow is more as measured in terms of RI and PI, and the blood flow volume through the involved vessel is decreased leading to a decrease in uterine tissue perfusion (Schonfelder 2005, Hussein *et al*. 2013).

Nevertheless, in comparison to the values of RI-IpsiUA and PI-IpsiUA before detorsion, their respective values decreased (P<0.05) after fetal delivery subsequent to successful uterine detorsion, and were almost similar (P>0.05) to their respective post-fetal delivery values of RI-ContUA and PI-ContUA (Table 1). These observations suggested a decrease in impedance of blood flow to uterus after fetal delivery subsequent to successful uterine detorsion as indicated by an increase (P<0.05) in blood flow volume (BFV-IpsiUA, Table 1), which indicated the recovery of blood perfusion to uterus subsequent to detorsion and fetal delivery (Elmetwally 2012). This is due to the fact that the involved blood vessels gets straightened after uterine detorsion, thus allowing more blood to flow.

The recording of Doppler indices in the middle uterine artery at the time of presentation of cattle with uterine torsion also suggested about the chances of survivability of the fetus (Fig. 3). In the middle uterine artery ipsilateral to the side of uterine torsion, the values of BFV-IpsiUA and TAP-IpsiUA were low (P<0.05), whereas the values of PI-IpsiUA were high (p>0.05) in the cases where the fetus after detorsion of uterus was delivered dead (Table 1), thus suggesting high impedance to blood flow towards uterus in these cases. Also, in humans, increased impedance of uterine and umbilical artery blood flow with elevated RI and PI ratios were associated with fetal death (Aardema *et al.* 2004). It is suggested that higher RI and PI and lesser blood flow through that vessel indicates the lesser chance of the survival of calf because source of nutrition to the fetus passes through that vessel. However, RI values were similar (P>0.05) between live calvers and dead calvers, because PI is more suitable than the RI when the flow is absent during all or part of diastole (Dickey 1997).

In conclusion, during uterine torsion, the blood supply to the uterus gets compromised and its severity defines the fetal survivability. After achieving detorsion, the middle uterine artery gets straightened and the blood supply to uterus starts resuming.

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