Review Article

Animal Reproduction Update

Year 2022, Volume-2, Issue-1 (January-June)

ACS Publisher
www.acspublisher.com

Ultrasonography in Uterine Torsion: A Futuristic Tool

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ARTICLE INFO

Key words: Adhesion, Buffalo, Doppler, Pixel, Uterine Torsion, Ultrasonography

doi: 10.48165/aru.2022.1204

ABSTRACT

The uterine torsion is one of the commonest encountered obstetrical ailments in bovine practice, thereby impending the postpartum performance and dairy economics. The lack of accurate diagnostic procedure for the degree and duration of torsion prevents the planning of appropriate treatment protocol. Furthermore, physical examination is not adequate in uterine torsion, therefore advanced diagnostic tools like ultrasonography could be a powerful tool to assess the prognosis of the clinical case. The usage of ultrasonography helps to detect uterine adhesions, degenerative changes in uterus and fetal fluid, fetal viability, further color Doppler ultrasound helps to know the uterine vascular perfusions. The advanced image analysis yields an unbiased interpretation of the sonogram. In the future, the combination of both greyscale ultrasounds with image analysis with the support of Doppler ultrasound may be used to predict the histological changes in the uterine wall.

Introduction

Bovine production and reproduction are severely affected by several factors including difficulties during pregnancy -gestational disorders- parturition and postpartum events. Amongst these uterine torsion is predominant in causing a major loss to farmers' economy. The uterine torsion has an impact on the health and profitability of dairy animals (Schonfelder and Hasenclever, 2005). Torsion is defined as the twisting of the uterus on its longitudinal axis, usually occurring in a gravid horn (Schonfelder et al., 2011). The anatomy of the bovine reproductive tract predisposes torsion during pregnancy (Roberts 1986; Noakes et al., 2001). Torsion is frequently reported at the end of gestation as a major cause of buffalo dystocia (Mishra et al., 2015). Usually, uterine torsion occurs before the onset or during the late first stage of parturition as the cervix is partially or completely dilated before or immediately after the correction of torsion. The uterine torsion has been reported in various species like bitch (Brown, 1974), guinea pig (Kunstyr, 1981), doe (Dhaliwal et al., 1986), rabbit (Hobbs and Parker, 1990), llama (Hopkins et al., 1991), camel (Cebra et al., 1997), ewe (Ijaz and Talafha, 1999), cattle (Cergolj et al., 1999), queen (Thilagar et al., 2005), buffalo (Prabhakar et al., 1994; Sutaria et al., 2015), mare (Jung et al., 2008; Sutaria et al., 2014a), and even in human (Jensen, 1992).

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Received 01.01.2022; Accepted 17.01.2022

Obstructive parturition including uterine torsion has a huge impact on dairy economics. Several causes have been identified for torsion, classified as either maternal or fetal or a combination of both. However, the predisposing factors/causes for uterine torsion are not well understood (Schonfelder and Sobiraj, 2005). Maternal factors involve attachment and musculature of the broad ligaments; enlargement and location of the pregnant uterine horn; type of housing; sudden movements; unsteady walk; age; unfilled rumen; body frame and hormonal profiles, whereas, fetal destabilizing factors include calf birth weight, sex, presentation, movements, reduced amount of the amniotic fluid and uterine tone (Ghuman, 2010). The affected animals will show a cessation of parturition along with general clinical colic signs, straining and partial anorexia. However, it requires immediate attention as it threatens the life of both the dam and fetus. For diagnosis of uterine torsion, per vaginal and per rectal examinations are required. The twisted vaginal passage on per-vaginum and twisted uterine horn with stretching of broad ligaments on the per-rectum gives the direction of uterine torsion. Often, animals suffering from torsion are being reported following a variable duration of onset of illness, thereby, the clinical signs related to endotoxemia become evident owing to longer duration, fetal death, severe degree of torsion, earlier handling, etc, The initially poor exhibition of signs and symptoms of uterine torsion, which subsides normally within 24-48 hours, is one of the factors for delayed presentation and diagnosis of this condition. In protracted cases of uterine torsion generalized bacteremia, endotoxemia, and/or cardiovascular failure results in the death of dam (Roberts, 1986). The uterine torsion can be successfully treated by modified Schaffer's method or laparohysterotomy/Cesarean section under the umbrella of fluid therapy, broad-spectrum antibiotics, analgesics, antihistaminics, and tonics whenever necessary to combat toxemia and shock before handling of cases if any. The modified Schaffer's method may not be successful in every case and may end up with complications like uterine rupture, intra-abdominal hemorrhages, damage/trauma to vital organs, abdominal wall lacerations and injury, etc. The dam survival can be increased in dams with a severe degree of uterine torsion having tissue compromise if treated surgically i.e., Cesarean section (Ghuman, 2010) and further to maintain the process of reproduction in the animal (Megahed, 2018).

A merely physical examination may not be adequate to diagnose and forecast the outcome of treatment. Advanced tools like ultrasonography including real-time B mode and color doppler will help solve the issue.

Ultrasonography

Ultrasonography is being used successfully to study animal reproduction for the past three decades (Kahn, 1992; Griffin and Ginther, 1992; Ginther, 2014). This tool has arisen as a precise non-invasive technique for the early pregnancy diagnosis (Herrera et al., 2007; Mehrajuddin et al., 2013; Pawshe and Purohit, 2013) and follicular wave development (Taneja et al., 1996; Manik et al., 2002; Barkawi et al., 2009). The ultrasonography has been accepted in many research and clinical usage during recent years, especially ovarian activity including follicular dynamics (Senatore et al., 2002; Honparkhe et al., 2004; Vecchio et al., 2012), fetal development, and sexing (Ali and Fahmy, 2008; Yotov et al., 2011), uterine involution (Sutaria et al., 2014b; Sutaria et al., 2018a), genital pathologies (Tandle and Purohit, 2013), and embryonic mortality (Campanile et al., 2005). Moreover, in recent years, trans-rectal, as well as trans-abdominal ultrasonography, has gained popularity for the diagnosis of pregnancy as well as fetal status in different animals. These advancements help in saving and maintaining the threatened pregnancy, thereby the use of ultrasonography in obstetrics, besides gynecology, is gaining popularity.

Indications of ultrasonography in uterine torsion

In animal reproduction, the female reproductive tract is regularly evaluated by ultrasonography due to its noninvasive nature (Ginther et al., 1989). The uterine twisting results in ischemia and cell death producing irreversible changes in the uterine wall i.e., loss of uterine wall elasticity and viability, and hence the uterine wall becomes necrosed, brittle, fragile, and prone to rupture (Baker, 1988; Pearson and Denny, 1975; Tamm, 1997; Noakes et al., 2001). Moreover, torsion of the uterus may also concurrently results in uterine perforation (Pickel et al., 1990), ovarian vein rupture (Blanchard, 1981), haemoperitoneum (Jadhao et al., 1993), rotation of urinary bladder (Kochhar et al., 1994), intestinal obstruction (Dhaliwal et al., 1992) and uterine adhesions with surrounding viscera (Siddiquee, 1988; McEntee, 1990; Sell et al., 1990). All the above-mentioned conditions could not be assessed or evaluated by physical examinations; hence the use of ultrasonography in uterine torsion is indicated. Devender et al. (2016a) have evaluated the uterus, fetal organs, fetal fluid, fetal viability, umbilicus by trans-abdominal ultrasonography, although failed to have fetal and dam prognosis while suffering from uterine torsion. Hence, it is required to be studied in-depth and evaluated with the use of recent

advancements in imaging technology especially ultrasonography including real-time B mode and color Doppler.

Methods and approach

The ultrasonography can be performed through both trans-rectal and trans-abdominal approaches. The useful modes for these examinations are real-time B mode and color Doppler. The trans-rectal ultrasonography is performed using a 5-10 MHz linear array transducer. The rectangular electric crystals are arranged side by side along the length in a linear array transducer producing rectangular images longitudinally oriented to the animal. The trans-abdominal ultrasound is performed using a 3-5 MHz convex transducer. The convex arrays are curved scanners that produce a sector like-field with a resolution similar to that of the linear array. The trans-abdominal probes have low frequency and longer wavelength; therefore, these probes are used for trans-abdominal ultrasonography because of long-distance penetration into soft tissues (Nyland and Mattoon, 1995). The detailed compiled information about these modes is depicted later in this text.

B-mode

B-mode ultrasound provides a great deal of information, a 2D diagnostic ultrasound represents echo interfaces; the intensity of the echo is represented by modulation of the brightness (B) of the spot, and the position of the echo is determined from the angular position of the transducer and the transit time of the acoustical pulse and its echo. B-mode ultrasound permits imagining and quantification of targeted anatomical structures, as well as diagnostic and therapeutic procedures. B-mode ultrasonography is most widely used for the examination of the large animal reproductive tract.

Trans-abdominal ultrasonography was performed in torsion suffered and healthy advanced pregnant buffaloes by Devender et al. (2016a) and shown usefulness to image fetal organs, uterine wall, fetal fluid, and placentomes. The hyperechoic uterine wall appears in both normal and torsion affected buffaloes over an anechoic fetal fluid, however, a significantly ($P<0.05$) thickened uterine wall was evident in torsion compared to normal pregnant buffaloes. Inflammatory changes were observed in the uterine wall having a longer duration of uterine torsion (Devender et al., 2016a; Sutaria et al., 2018b). Amniotic fluid appeared as a hypoechoic with diverse echoic particles on ultrasonography (Jonker, 2004; Devender et al., 2016b), whereas the echogenicity of allantoic fluid was lower than the amniotic fluid. The uterine fluids, amniotic and allantoic are separated by a thin hyperechoic amniotic membrane. The echogenicity of the allantoic fluid slowly increases during the pregnancy (Jonker, 2004; Kohan-Gadr et al., 2008).

The echogenic ovoid to elongated structures similar to hen egg-sized arranged in a row on the hyperechoic uterine wall and encircled by the anechoic fluid are placentomes. The placentomes were healthy and no sign of degeneration in normal advanced pregnant buffaloes compared to degenerated morphological changes viz., hypoechoic parenchyma in placentomes of uterine torsion affected buffaloes. The size of placentomes was observed to be lower in uterine torsion cases than in normal pregnancy ($P>0.05$) (Devender et al., 2016a). The placentae diameter measurement could be a useful asset valuable resource in diagnosing abnormal pregnancies in cows (Buczinski et al., 2007).

Real-time B-mode trans-rectal ultrasonographic (USG) examination using an 8 MHz probe was performed in Sindhi mare suffering from uterine torsion by Dabas et al. (2014). The ultrasonography has been also used to assess fetal viability and uterine status in goats, buffaloes, and cows (Sutaria, T.V., Personal communication). The study to diagnose uterine adhesions in 16 buffaloes with a history of uterine torsion during advanced pregnancy was conducted by Sutaria et al. (2018b). The adhesions were diagnosed by trans-rectal and abdominal real-time B-mode ultrasonography and confirmed during treatment. Based on the echogenic morphological appearance of the uterine wall, fetal fluid and placentomes adhesions were categorized into diffuse, fibrin bands and no adhesions. The buffaloes with diffuse adhesions (6/16, 37.50%) were subjected to Cesarean section, whereas buffaloes with fibrin bands (4/16, 25.00%) and no adhesions (6/16, 37.50%) were directly subjected to rolling by modified Schaffers' method (10/16). Buffaloes failed to be detorted (1/10, 10.00%) and with partial and/or no cervical dilation was treated by Cesarean section (7/9). Dam survival was 66.66 (4/6), 25.00 (1/4), and 83.33 (5/6) % with diffuse, fibrin bands and no uterine adhesion groups, respectively. The adhesions and degenerative changes of uteri are coupled with the duration and degree of torsion.

Color Doppler

The blood flowing to, away, or at an angle to the transducer will produce a multicolor image in color Doppler ultrasonography (red= toward the transducer; blue= away from the transducer). The fetal heart, corpus luteum, and ovulation are monitored through Doppler ultrasound during clinical work. The uterine blood supply has been evaluated in cattle (Bollwein et al., 2002), buffalo (Varughese et al., 2013), and mare (Bollwein et al., 2004) using trans-rectal

color Doppler ultrasonography. The ovarian torsion in humans is diagnosed based on color and spectral Doppler analysis of the ovarian arterial and vascular waveforms (Shadinger et al., 2008). The middle uterine artery supplies uterine structures, which increase in diameter indicates advanced pregnancy followed by an increase in the supply of blood to the fetus. Any alteration in the middle uterine artery decreases the blood supply to the uterus culminating in uterine changes as well as affecting the living fetus. The blood flow in the middle uterine artery correlates with the degree and vascular constriction, ultimately blood flows velocity and resistance too; therefore, the blood flow is nadir to nil in 360° uterine torsion (Schonfelder et al., 2005). The uterine artery is free movable in a broad ligament placed parallel to the external iliac artery. The semi-quantitative blood flow in the middle uterine artery is evaluated based on pulse/spectral waveforms near the rudimentary umbilical artery. These waveforms are the graphical representation of frequency shift in blood flow (Fig. 1), which should be obtained with the utmost care, avoiding animal movements and steady positioning of the probe in the rectum. The most useful Doppler indices for appraising the blood flow in vessels are pulsatility index (PI), resistance index (RI), time-averaged maximum velocity (TAMV), and blood flow volume (BFV) (Dickey, 1997).

The values of the Doppler indices in both uterine arteries did not differ significantly in normal advanced pregnancy, whereas, pulsatility index (PI) and resistance index (RI) were significantly high ($P<0.01$) in ipsilateral than contralateral artery of uterine torsion (Hussein, 2013). Further, blood flow volume and peak velocity in uterine torsion were significantly shorter on the ipsilateral side than the contralateral side of torsion. The noted changes in Doppler indices are due to compression of the middle uterine artery during uterine torsion. The early diastolic notch (an area of no blood flow) has been constantly perceived in uterine torsion that is symbolic of poor blood perfusion to the uterine wall (Hussein, 2013). The pre-diastolic notches in both ipsilateral and contralateral middle uterine artery endorse hindrance in blood flow while the absence of diastolic flow signifies severe degree and long-standing cases of torsion, ultimately predicting fetal viability (Singh et al., 2016). The narrowing of the arterial lumen produces pre-diastolic notch suggestive of impedance and poor blood perfusion (Abuhamad et al., 1995; Harrington et al., 1996; Hussein, 2013), and the rise in vascular resistance in severe cases of uterine torsion is depicted as the absence of diastolic flow on the spectral waveform (Dickey, 1997). The distinguish high systolic flow with the absence of early diastolic blood flow of the middle uterine artery was observed in uterine torsion compared to normal pregnancy (Hussein, 2013). The duration and degree of torsion are inversely related to the vascular blood flow, therefore chances of fetal survival reduce with increased degree and duration of torsion resulting in reduced blood flowing through the middle uterine artery, a source of nutrition to the fetus (Singh et al., 2016).

The declined pulsatility index (PI) and resistive index (RI) during the gestation were recorded in Murrah buffaloes, which may be due to gradual placental maturation, increased tertiary villi, and increased fetal blood flow and umbilical diameter (Singh et al., 2017). The researcher-clinician uses RI and PI to appreciate the vascular perfusion (Urban et al., 2007) because both RI and PI are not affected

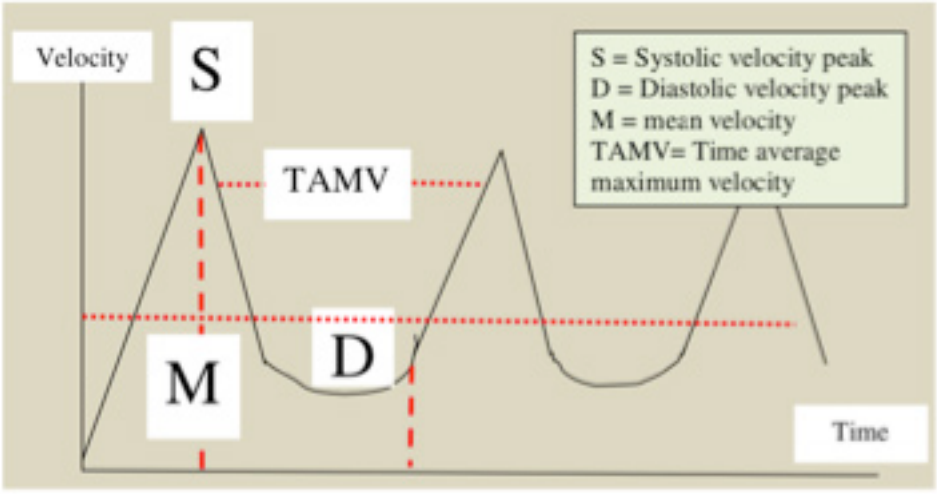

Fig. 1: Graphical presentation of Doppler shift to calculate Doppler Indices.
Doppler indices: RI= (S-D)/S (Resistance index, Pourcelot, 1974);
PI = (S-D)/M (Pulsatility index, Gosling and King, 1974);
S/D (Systolic/Diastolic Ratio), Stuart, et al., 1980). (Adapted from Dickey, 1997 and cited from Hussein, 2013).

by either Doppler angle or blood vessel diameter but only by the heart rate (Maulik, 1993). Though, the pulsatility index was found to be advantageous over the resistive index when a part or complete absence of diastolic flow is observed (Dickey, 1997). The study on cardiac blood flow patterns was conducted by Devendra et al. (2015) in buffaloes suffering from uterine torsion using a Sonoscape color Doppler ultrasound device with a 2-5 MHz transducer. They found the pattern of blood flow in normal pregnant buffaloes in advance gestation was different from that of blood flow in uterine torsion-affected buffaloes. In normal pregnant buffaloes, the pattern of blood flow was biphasic with both peaks that are systolic and diastolic, but not as much higher as in uterine torsion. On the other hand, in uterine torsion affected buffaloes the velocity waveform of the maternal heart showed high systolic flow and absence of early diastolic flow indicating pressure on the heart, and therefore changes were observed in blood flow pattern (Devender et al., 2015).

Presently, there is no accurate method for the diagnosis of the degree and duration of uterine torsion; hence, the prognosis couldn't be predicted in torsion-affected bovines. Moreover, scarce literature is available on uterine blood flow. Therefore, the application of color Doppler in assessing uterine perfusion in torsion may be proved to be a boon in predicting future fertility.

Quantitative ultrasonography

The recent advancements in computer technologies, i.e., image analysis, sonograms can be successfully effectively and efficiently evaluated; objectively unbiased rather than conventional subjective biased assessment (Kucukaslan et al., 2014). The method of analyzing pictorial information is image processing (Lo and Puchalski, 2008; Osmanog lu et al., 2018). The numerical data are obtained from image analysis and subjected to statistics (McAndrew, 2004; Osmanog lu et al., 2018). The visual evaluation of the image is presented between 18 and 20 grey tones (Baxes, 1994), hence becoming limited and more accurately evaluated using computer software. The ultrasonogram is considered a two-dimensional image (horizontal and vertical axis) being expressed in greyscale and measured in a unit i.e., pixel. The greyscale is determined by a brightness value between 0 and 255 pixels. The ultrasonic image will yield different numerical values in terms of pixels based on the echo difference of tissues (Iskender, 2009; Ozkan, 2012). The saved ultrasonographic images in bitmap/jpeg file format can be analyzed using software (Image J/photoshop/FIJI/MatLab/Ashampoo® Photo Optimizer, MIPAR/Franzis Color projects) on the computer (Windows or macOS).

The MPV (mean pixel values) of fetal fluids were measured ultrasonographically in buffalos suffering from uterine torsion by Devender et al. (2016a,b) and found significantly higher ($P<0.05$) MPV of fetal fluids in uterine torsion than the normal advanced pregnant buffaloes. Additionally, mean pixel values measured by trans-abdominal ultrasonography were significantly higher ($P<0.05$) than the pixel values measured by trans-rectal ultrasonography in both normal and torsion suffered buffaloes. These observations could be useful to determine the duration and severity of uterine torsion The pixel values of Murrah buffaloes fetal fluid (40.44±1.19 to 36.72±2.33) measured in computer-based "Adobe Photoshop" software varied non-significantly during 4^{th} to 10^{th} month of gestation (Singh et al., 2017).

The quantitative ultrasound study was conducted by Sutaria et al. (2019) on 33 advanced pregnant Mehsana buffaloes suffering from uterine torsion for 1-15 days, grouped into two i.e., buffaloes with uterine adhesion (Group I) and buffaloes with no uterine adhesion (Group II) based on ultrasonographic findings. The trans-abdominal and trans-rectal ultrasonography was performed using a 2-5 MHz convex transducer and 5-10 MHz linear-array transducer, respectively. The sonograms for quantification were taken in real-time B-mode using a sonography unit (M Vet-Turbo, Fujifilm SonoSite) operated using its default gain levels. The frozen ultrasonograms were transferred to a computer in JPEG format and mean pixel values of these grayscale images were obtained using Image J software (1.52q, National Institute of Health, USA). The mean pixel values of uterine wall at 7, 13, and 15 cm depth were 82.94 ± 1.31, 57.89 ± 2.55 and 72.23 ± 3.53 in Group I, whereas, corresponding values for Group II were 74.30 ± 0.96, 48.35 ± 1.58, and 52.04 ± 2.55. The statistical analysis revealed significantly ($P<0.05$) high mean pixel values in Group I as compared to Group II indicating association of mean pixel values with uterine adhesions. Thus, real-time B-mode ultrasound can be used to know uterine health.

The differences in mean grey level (MGL) of uterine ultrasonography during early pregnancy might be attributed to histological structural changes in the endometrium, hence, higher ($P<0.05$) MGL values in non-pregnant estrus ewes compared to early pregnant ewes (Akbulut and Celik, 2021). Therefore, MGL can be a useful aid for early pregnancy diagnosis in ewes (Akbulut and Celik, 2021).

Conclusions and future prospects

Merely physical examination is not adequate in cases of uterine torsion, therefore advanced diagnostic tools like

ultrasonography could be a powerful tool to assess the prognosis of the clinical case. The color Doppler ultrasonography gives clear-cut ideas about vascular perfusion in cases of uterine torsion, thereby probable tissue compromisation. The quantitative assessment of ultrasonographic images will give us an unbiased interpretation of uterine health status. Thus, in nutshell, the use of ultrasound in uterine torsion will help in appropriate clinical evaluation, planning of obstetrical maneuvers, and prognosis.

In the future, the combination of both greyscale ultrasounds with image analysis with the support of Doppler ultrasound may be used to predict the histological changes in the uterine wall.

Competing Interest

There is no conflict of interest among the authors.

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