ULTRASONOGRAPHIC MORPHOMETRY OF RETICULUM IN CATTLE AND BUFFALOES SUFFERING FROM TRAUMATIC RETICULO-PERITONITIS

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ABSTRACT

The objectives of the study were to evaluate the ultrasonographic morphometry of the reticulum in healthy non-gravid cattle and buffaloes from right and left parasternal and lateral windows and to evaluate the role of ultrasonography in the prediction of penetrating metallic foreign bodies in the reticular wall in cattle and buffaloes. The study included 22 clinically healthy (11 cross-bred Indian cattle (*Bos tarus* and *Bos indicus*) and 11 Indian water buffaloes (*Bubalus bubalis*)) and 26 traumatic reticulitis affected bovines (21 cattle and 15 buffaloes). Various parameters like, reticular wall thickness, depth of reticulum, pattern of reticular motility and wall, and presence of effusions were recorded to assess the penetrability of metallic sharp foreign body using ultrasonography.

The reticular wall thickness varied from 0.34 to 0.82 cm and 0.37 to 0.68 cm in healthy cattle and buffaloes, respectively. In both the species, the mean highest reticular wall thickness was recorded on the left lateral side. Instead of typical biphasic motility, folding type motility was recorded in 72.73% healthy buffaloes and 27.27% healthy cattle from the left lateral side. The reticular wall pattern was recorded to be smoother in healthy buffaloes from all the windows compared to healthy cattle.

The peri-reticular reaction in diseased bovine was least observed on the left lateral aspect of the reticulum and was maximum evident on the left ventral aspect of reticulum in cattle and the right ventral aspect in buffaloes. The reticular motility was present in maximum number of bovine despite adhesions present on rumenotomy. The cattle showed more adhesions for partially penetrating foreign bodies, compared to buffaloes. Despite non-penetrating foreign bodies, the peri-reticular effusions were seen on the ventral aspect of reticulum from both sides, though in less quantity.

In conclusion, the peri-reticular effusions are maximum seen on the left ventral aspect in cattle and right ventral in buffalo in completely and partially penetrating foreign bodies; however, effusions may also be present in non-penetrating foreign body in cattle.

Keywords: buffaloes, *Bubalus bubalis*, ultrasound, bovine, cow, reticulitis, foreign body

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INTRODUCTION

Ingestion of foreign bodies is a common problem in bovines. The ingested foreign bodies may injure or penetrate the reticular wall and is known by different names like Foreign body syndrome (FBS), traumatic reticulo-peritonitis (TRP), hardware disease or sharp foreign body syndrome (SFBS) (Aref and Abdel-Hakiem, 2013). The bovine suffering from TRP show non-specific clinical signs of partial to complete anorexia, scanty feces, fever, loss of rumination and bloat. These clinical signs are not confirmatory for the diagnosis of foreign bodies in the reticulum and require radiography of the reticulum. Radiography is the primary and is one of the most reliable tool to diagnose metallic foreign bodies in the reticulum of bovines (Makhdoomi *et al*., 2018). Radiography of TRP is reported to be 76% to 83% sensitive, 90 to 93% specific, 85% accurate with 92% positive predictive and 80% negative predictive values (Partington and Biller, 1991; Braun *et al*., 1993). But radiography has limitation that it cannot confirm anything about the soft tissue variations in the peri-reticular space.

Ultrasonography is a recent diagnostic modality for evaluating the reticulum and adjoining organs in TRP affected Bovines. Several studies have been published on the use of ultrasonography for the assessment of reticular health in cattle (Braun and Rauch, 2008) however; a few such studies exist in buffaloes (Abdelaal *et al*., 2009; Abdelaal and Floeck, 2015). Ultrasonographically, it is possible to depict the actual picture of reticulum and the surrounding organs including its motility, peri-reticular reactions, effusions, echogenic masses, abscesses and displacement of organs. On rare instances foreign bodies may be located in the reticulum, ultrasonographically, based on the comet tail artifact or the acoustic shadowing (Abdelaal and Floeck, 2015). The reticular foreign bodies may be classified as potential (which are sharp and metallic on radiograph and appear to have the potential to penetrate the reticular wall or the adjoining structures like the wires, needle, nails etc) or non-potential (which may be metallic or non-metallic and do not appear to have the potential to penetrate the reticular wall on radiograph like nut bolts, key, chain, coins, rings, anklets, stones etc) (Chaudhari *et al*., 2009; Makhdoomi et al., 2018). There is lack of literature on the comparison of ultrasonographic morphometry of reticulum in healthy cattle and buffaloes. Objective assessment of reticular morphometry in cattle and buffalo having sharp metallic foreign bodies may help in decision making for rumenotomy or culling. The present study focuses on the use of ultrasonography to assess the status of potential metallic foreign body present on the radiograph to be penetrating the reticular mucosa or non-penetrating. Reviewing the previous studies, the present study was designed with the following objectives:

1. To compare the ultrasonographic morphometry of reticulum in healthy non-gravid cattle and buffaloes.

2. To evaluate the role of ultrasonography in the prediction of penetrating metallic foreign bodies in the reticular wall in cattle and buffaloes.

MATERIALS AND METHODS

This was a clinical study and was duly approved by the Institutional Animal Ethics Committee. The study was done in 2 parts:

Part I.

It included 22 clinically healthy non-

gravid adult bovines (11 cross-bred Indian cattle (*Bos tarus* and *Bos indicus*) and 11 Indian water buffaloes, *Bubalus bubalis*) which were subjected to ultrasonography of the reticular region in non-sedated standing position. The reticulum was evaluated in B and B+M modes using 2 to 5 MHz convex multi-frequency transducer on Wipro Logiq 3 expert ultrasound machine. The reticulum was scanned from four windows; right lateral, right ventral, left lateral and left ventral. Right and left lateral ultrasound windows were chosen at the 6th ICS just at the level of elbow, whereas the ventral windows were lateral to the sternum (parasternal) at the level of xiphoid, holding the transducer in cranio-caudal direction and slightly outward.

The clinical parameters of age and weight of all the bovine were recorded. The ultrasonographic parameters recorded from the four windows measured using inbuilt ruler in the machine software included:

1) The reticular wall thickness (in cm). It was measured in the B+M mode (Figure 1).

2) The Amplitude (in cm) of reticular motility in phase I, II and III by keeping the cursor at the middle of the visible reticular wall (Figure 2).

3) The thickness of liver (from right lateral side) and spleen (left lateral side) in centimetres (Figure 3).

4) The contour of the reticular wall as smooth or wavy (Figure 4).

5) The motility pattern of the reticulum as monophasic, biphasic or tri-phasic or any other pattern (Figure 5).

Part II.

It included 36 bovines (21 cattle and 15 buffaloes) diagnosed with sharp metallic foreign body in the reticular region, radiographically, and were subjected to surgical intervention for the removal of foreign body through rumenotomy. All the bovine were subjected to ultrasonography in B and B+M modes from all the four windows as described in part I. The detail of number of bovines subjected to various ultrasonographic windows is depicted in the Table 1.

In one buffalo the right ventral was not scanned due to the presence of ventral oedema on the right side. In two cattle the reticulum was not visible from right side due to pushing of other abdominal organs and in one cattle the liver was enlarged enough to push the reticulum caudally and dorsally.

Apart from the clinical parameters recorded in part I of the study, part II also included the duration of disease condition, type of feces, history or presence of bloat and the stage of pregnancy. In addition to the ultrasonographic parameters recorded in part I, the nature and extent of effusions present in the peri-reticular region from various windows were also studied in TRP affected cattle and buffaloes.

All the bovines of part II were subjected to left flank exploratory rumenotomy for the retrieval

Table 1. Number of bovines subjected to various ultrasonographic windows.

Species	Right lateral	Rightventral	Left lateral	Left ventral
Cattle (n=21)	19	19	21	21
Buffalo (n=15)	15	14	15	15

of foreign bodies from the reticulum under local para-vertebral anaesthesia using inj. lignocaine hcl (2%). The foreign bodies retrieved were matched with those seen on radiographs and were classified as completely penetrating (cp; where no part of foreign body was touchable in the reticular lumen and was removed either by piercing through the reticular wall or by giving a blind stab incision to the reticular wall as described by Sangwan *et al*., 2018), partial penetrating (pp; where a small portion of foreign body was felt in the reticular wall or lumen while the rest was piercing in the wall or the adjoining structures and was retrieved by pulling only) and the non-penetrating (np; when the foreign bodies were lying free in the reticular lumen). The bovines with various types of foreign bodies (cp, pp and np) were classified and the ultrasonographic findings were correlated.

Statistical analysis

The data generated was grouped and was subjected to statistical analysis using Microsoft Office Excel, 2007. The mean and the standard deviation of all the numerical parameters were calculated in all the bovines. The student t-test was applied to test the significance of differences in the clinical and ultrasonographic parameters in different groups (in between different ultrasonographic windows and in between same ultrasonographic window for healthy and TRP affected cattle and buffaloes).

RESULTS AND DISCUSSION

Part I (Table 2)

A total of 22 healthy non-gravid bovines (11 cattle and 11 buffaloes) were studied with an objective to evaluate the differences between the ultrasonographic features of the reticulum based on the species (cattle and buffalo) and the ultrasonographic windows for reticulum (right and the left lateral and ventral). The detailed values of part I are depicted in Table 2.

The reticular wall thickness varied from 0.34 to 0.82 cm and 0.37 to 0.68 cm in cattle and buffaloes respectively. The variation in the reticular wall thickness might be due to the honey comb pattern of the wall, with depressions and elevations. On student t-test application, the reticular wall thickness from the left lateral window was found to be significantly (P=0.03) higher than that from the right lateral window in cattle, however, in buffalo the reticular wall thickness from the right lateral window was significantly (P=0.05) thicker compared to the right ventral window. In buffaloes, when the reticular wall thickness from the ventral windows was compared, the left ventral was found to be significantly (P=0.04) thicker than that of the right. However, in both the species, the mean highest reticular wall thickness was recorded on the left lateral side.

Biphasic reticular motility was recorded in all the bovines from all the windows except in one buffalo from the left ventral window in which the reticulum was monophasic. Triphasic motility of reticulum was also observed in few bovines from various windows. It was observed that the reticulum from the left lateral window do not show the typical biphasic or triphasic motility as recorded on B+M mode; instead, this motility was classified as folding type motility (Figure 6). This folding type motility was recorded in 72.73% buffaloes (n=8) and 27.27% cattle (n=3) from the left lateral side.

From the lateral windows, the reticulum moved medially during the motility, while from the ventral side the reticulum moved cranio-medially.

Table 2. Mean ± Sd of ultrasonographic features of reticulum from various windows in healthy cattle and buffaloes.

S. No.	Parameter	Cattle (N=11)				Buffalo (N=11)			
		Right lateral	Right ventral	Left lateral	Left ventral	Right lateral	Right ventral	Left lateral	Left ventral
1	Body wt (kgs)	390.27 ±80.65 (300-510)	390.27 ±80.65 (300-510)	390.27 ±80.65 (300-510)	390.27 ±80.65 (300-510)	433.55 ± 71.66 (350-500)	433.55 ± 71.66 (350-500)	433.55 ± 71.66 (350-500)	433.55 ± 71.66 (350-500)
2	Age (yrs)	4.55 ± 1.52 (3-8)	4.55 ± 1.52 (3-8)	4.55 ± 1.52 (3-8)	4.55 ± 1.52 (3-8)	4.64 ± 1.14 (3-7)	4.64 ± 1.14 (3-7)	4.64 ± 1.14 (3-7)	4.64 ± 1.14 (3-7)
3	Reticular wall thickness (cm)	0.96 ± 0.42 (0.59-1.51)	1.06 ± 0.93 (0.41-3.14)	1.38 ± 0.40 (0.82-1.99)	0.65 ± 0.28 (0.34-1.15)	1.26 ± 0.67 (0.5-2.41)	0.79 ± 0.24 (0.43-1.32)	1.36 ± 0.61 (0.68-2.41)	1.19 ± 0.51 (0.37-2.06)
4	Depth of phase I motility (cm)	3.83 ± 2.03 (0.89-7.06)	3.9 ± 1.52 (1.55-5.8)	4.45 ± 1.8 (1.85-7.73)	4.04 ± 2.36 (1.4-7.22)	4.64 ± 2.36 (1.9-9.99)	3.69-2.1 (1.1-7.75)	4.96 ± 3.68 (1.73-10.49)	5.43 ± 1.58 (3.43-6.18)
5	Depth of phase II motility (cm)	4.53 ± 2.58 (1.76-9.2)	4.59 ± 1.79 (2.88-8.39)	5.06 ± 2.18 (3.02-8.59)	6.84 ± 2.72 (3.53-10.03)	6.06 ± 2.25 (3.22-10.33)	5.55 ± 2.71 (1.67-9.17)	5.32 ± 2.68 (1.99-9.26)	6.29 ± 1.42 (4.31-8.03)
6	Depth of phase III motility (cm)	2.92 ± 0.44 (2.63-3.43)	6.7 ± 2.59 (4.87-8.53)	4.41 (single case)	7.29	7.93 ± 0.6 (7.51-8.35)	2.94 (single case)	nil	6.37 (single case)
7	Liver or spleen thickness (cm)	2.79 ± 1.06 (0.86-3.82)	nil	3.12 ± 1.33 (1.58-4.82)	2.54 (one case)	2.96 ± 0.93 (1.57-3.91)	3.33 (seen in one case)	2.74 ± 1.13 (0.86-4.56)	3.55 (one case)
8	Depth of reticulum in resting state (cm)	4.58 ± 1.24 (3.5-6.91)	4.31 ± 0.76 (3.41-5.15)	6.01 ± 1.87 (4.0-9.25)	4.75 ± 1.17 (3.18-6.03)	4.9 ± 1.13 (4.17-6.59)	4.5 ± 1.10 (2.59-6.59)	6.3 ± 1.6 (3.88-8.59)	5.09 ± 2.36 (2.75-8.67)
9	Reticular wall contour								
	Smooth	7/11=63.64%	9/11=81.82%	6/11=54.54%	8/11=72.73%	10/11=90.90%	11/11=100%	11/11=100%	11/11=100%
	Wavy	4/11=36.36%	2/11=18.18%	5/11=45.45%	3/11=27.27%	1/11=9.1%	0	0	0
10	Reticular motility								
	Monophasic	0	0	0	0	0	0	0	1/11=9.1%
	Biphasic	8/11=72.73%	9/11=81.82%	7/11=63.64%	10/11=90.9%	9/11=81.82%	10/11=90.9%	0	9/11=81.81%
	Triphasic	3/11=27.27%	2/11=18.18%	1/11=9.1%	1/11=9.1%	2/11=18.18	1/11=9.1%,	0	1/11=9.1%
	Folding	0	0	3/11=27.27%	0	0	0	8/11=72.73%	0

This led to the limitation of measuring the amplitude of motility in B+M mode. Therefore, in ventral windows, the cursor for amplitude measurement was placed at the centre of the visible reticular wall. This helped in viewing and measuring the amplitude of phase I of the motility on B+M mode, but phase II amplitude was still not seen within the screen. This placement of cursor also reduced the amplitude by half the visible reticular wall length as the reticulum contracts from the ventral tip. Thus, the values of amplitude depicted for phase I motility from the ventral windows are approximately 4 to 5 cm less than the exact amplitude. The amplitude of the reticular motility in phase I was measured from the wall of the reticulum in resting state and not from the transducer. So, in this study the amplitude of phase I reticular motility ranged from 0.89 to 7 cm in cattle and 1.1 to 9.9 cm in buffaloes, which otherwise may be from 4.89 cm to 11 cm in cattle and 5.1 to 13.9 cm in buffaloes, if we add the remaining length of reticulum. However, no significant difference was found in the amplitude of reticular motility from various windows in both the species and between the species.

In most of the cases, the reticulum was seen going out of ultrasound screen during the 2nd phase of motility. The second phase of motility was observed to be starting from almost the half the amplitude of the 1st phase of motility. Therefore, the amplitude of reticular motility in 2nd phase was recorded from the point from where it starts after returning from the 1st phase.

The phase III of the reticular motility was seen in few bovine and was too deep, that was partially recorded. However, no significant difference was calculated in the amplitude of phase III motility from various windows in both the species and between the species.

The liver from the right lateral and the spleen from the left lateral aspect were seen on 6th ICS in all the bovine in the same window from where reticulum was seen. However, no significant difference was calculated in the thickness of liver or spleen seen from various windows in both the species. In one case each of cow and buffalo the spleen was also seen from the left ventral window, displacing the reticulum away from the diaphragm. Similarly, in one buffalo, the liver was seen from the right ventral window. So, liver and spleen can be occasionally seen on the respective ventral windows in healthy bovine.

In resting state, the reticular wall was seen at the maximum depth from the left lateral window in both the species, though statistically, it was significant only in buffalo (P=0.029) when compared between right and left lateral window. This might be due to the presence of more thick spleen lateral to the reticulum, or more muscles or thicker skin on that aspect in buffalo.

The contour of the reticular wall was recorded to be smooth in buffaloes from all the windows except in one case in which it was slightly irregular from the right lateral side. However, in cattle the smooth contour of the reticular wall varied from 54.54% from the left lateral to 81.82% from the right ventral window. The contour was wavy in few cattle from various windows (Table 2). This might be due to the rapid respiration of the cattle, as the reticulum is closely associated with the diaphragm.

Part II

The ultrasonographic features of reticulum and peri-reticular region from the four windows were classified based on the status of foreign body on rumenotomy i.e. completely penetrating (cp), partially penetrating (pp) and non-penetrating (np).

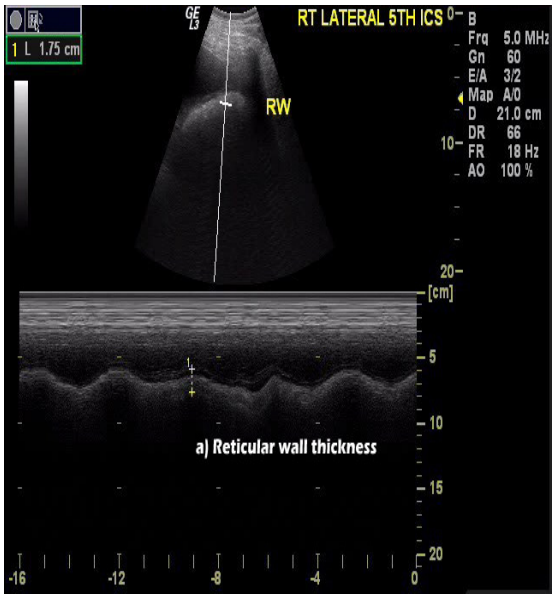


Figure 1. Ultrasonogram showing measurement of reticular wall thickness

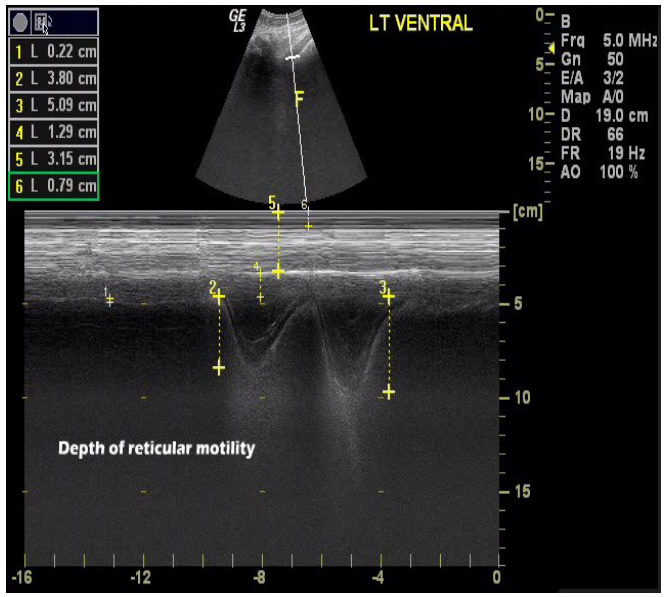


Figure 2. Ultrasonogram showing amplitude of reticular motility

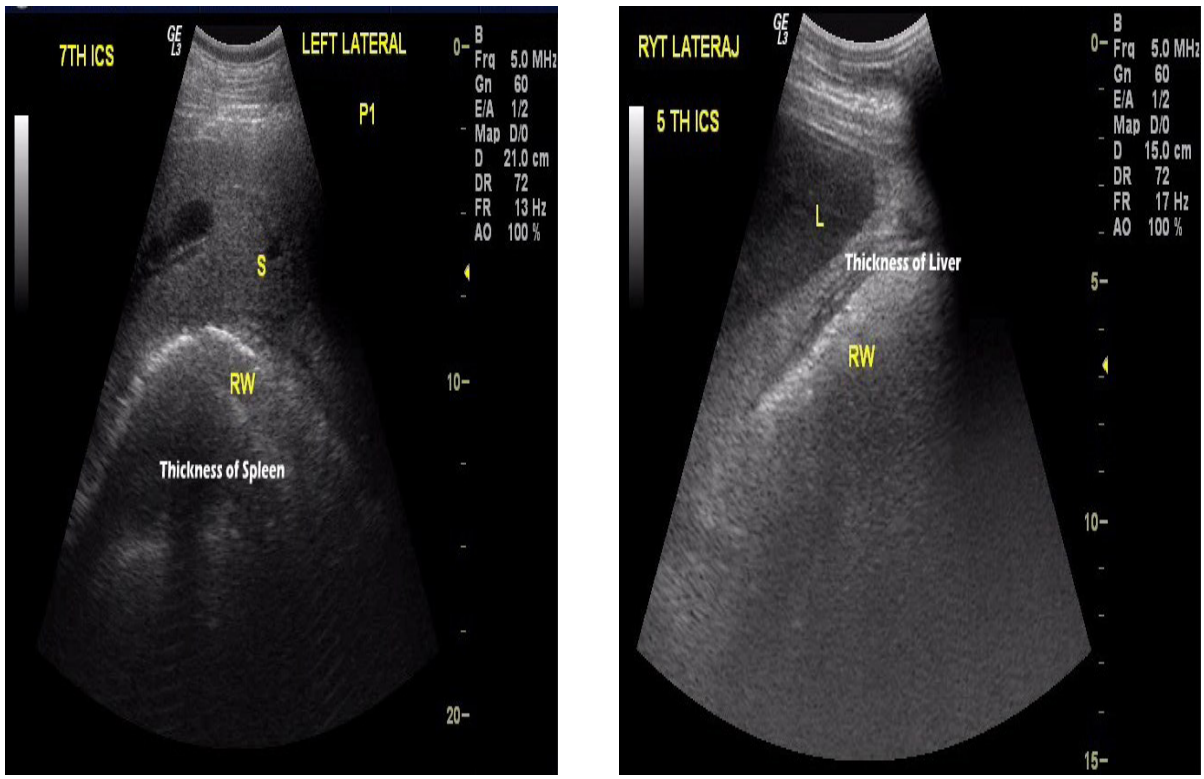
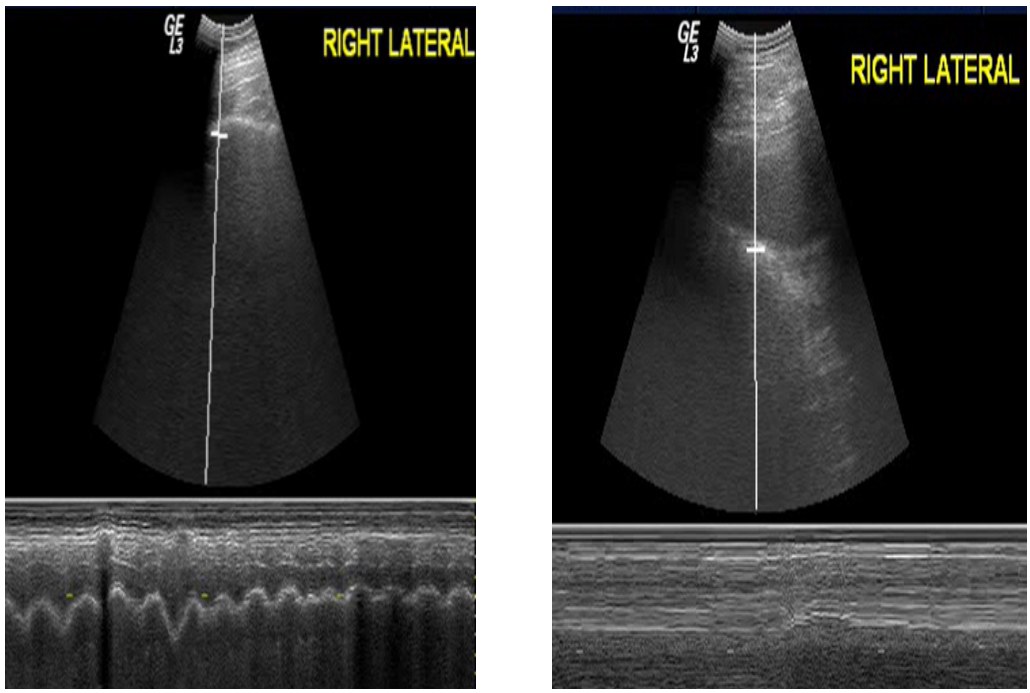


Figure 3. Ultrasonogram showing spleen (S) and liver (L) along with reticular wall from the left and right lateral window respectively



4a 4b

Figure 4. Ultrasonogram showing wavy (4a) and smooth (4b) reticular wall contour.

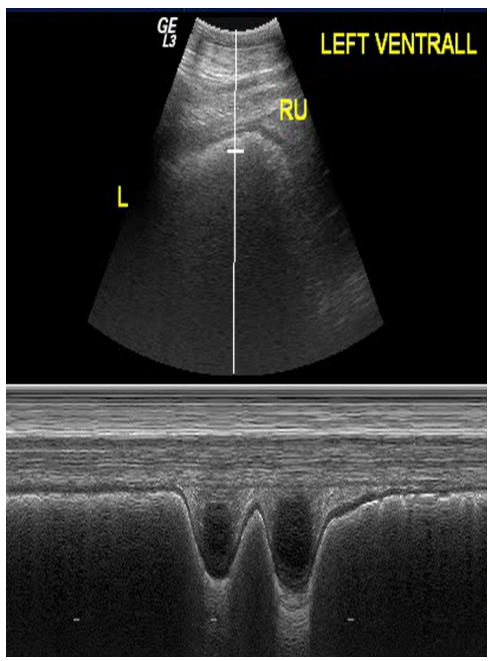


Figure 5. Ultrasonogram showing biphasic reticular motility in B+M mode.

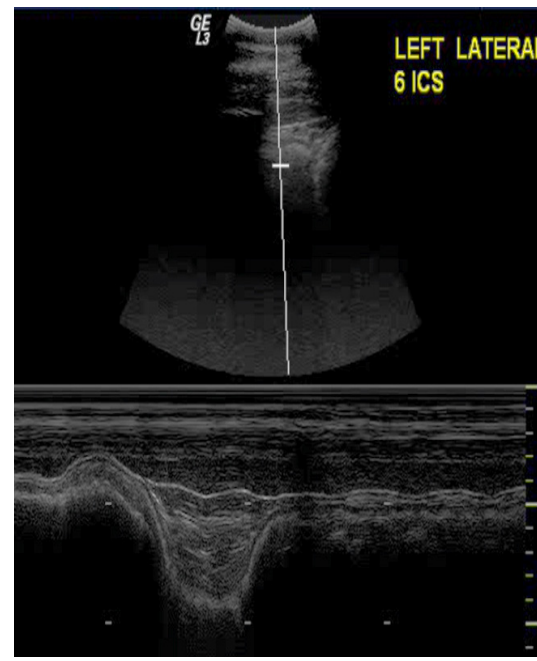


Figure 6. Ultrasonogram showing folding type motility from left lateral aspect.

1) Ultrasonographic findings of completely penetrating foreign bodies in cattle and buffaloes (Table 3)

A total of 16 bovine (9 cattle and 7 buffaloes) had completely penetrating foreign bodies and were scanned for ultrasonography. The average age, body weight and body width of cattle and buffaloes with completely penetrating foreign bodies were 4.77±1.29 years, 404.92±97.41 kgs, 35.18±6.09 cms and 6.42±2.25 years, 448.14±68.60 kgs, 42.66±4.63 cms respectively. The age of cattle suffering from TRP and having completely penetrating foreign body was significantly less (P=0.0011) compared to that of buffaloes having completely penetrating foreign body.

Right lateral ultrasound window

No statistically significant difference was recorded in the objective parameters of the reticulum recorded from the right lateral window in cattle and buffaloes. On rumenotomy, adhesions on two or more walls of reticulum were recorded in 8 cattle (88.88%) having completely penetrating f.b's. A nodule and a diaphragmatic abscess were also found in two cattle with completely penetrating foreign bodies on rumenotomy but were not seen from right lateral window.

Biphasic or folding type reticular motility was present in 77.77% (n=7) (33.33% biphasic and 44.44% folding) of cattle from the right lateral window. However, in buffaloes the reticular motility was recorded in 100% (57.14% biphasic and 42.86% monophasic) animals from this window and the adhesions were felt in 71% (n=5) buffaloes. The amount of adhesions were assessed based on the amount of reticular region involved and were found to be more in cattle compared to buffaloes. The amplitude of reticular motility in different phases was recorded to be reduced in some animals but was not found statistically significant from the healthy bovine. Biphasic reticular contractions with abnormal amplitude and frequency had been reported in cows with TRP, but the number of contractions can also be reduced or can be slower than normal (Braun *et al*., 1993; Ramprabhu *et al*., 2003; Kumar *et al*., 2007; Streeter and Strep, 2007; Singh *et al*., 2013; Abdelaal and Floeck, 2015; Gouda, 2015). Hyper-motile reticular contractions in cows with vagal indigestion secondary to traumatic injury by perforating foreign bodies have also been reported (Braun, 2009).

Peri-reticular effusions in the form of fluid or echogenic masses were present in 4 TRP cattle (44.44%) having completely penetrating foreign body (Figure 7). The column of effusions visualized from the right lateral window ranged from 0.71 to 5.46 cm. The two cases with diaphragmatic abscess and nodular masses or chord with embedded foreign body could not be visualized from this window. However, in buffaloes, only two cases (24.57%) had mild and echogenic masses seen from the right lateral window. The findings of peri-reticular effusions in TRP cattle and buffaloes had also been reported by various scientists although they are not classified as per the windows or completely penetrating status (Braun *et al*., 1993; Ramprabhu *et al*., 2003; Braun, 2005; Streeter and Strep, 2007; Omidi, 2008; Abdelaal *et al*., 2009; Braun, 2009; Abdelaal and Floeck, 2015; Abdelaal *et al*., 2016; Kumar *et al*., 2018). The depth of reticulum at resting stage from right lateral window was found to be more in cattle compared to buffalo (but not statistically significant), may be because of more amount of peri-reticular reaction in that region in cattle.

Liver was visualized in 33.33% TRP cattle (n=3) having completely penetrating foreign body

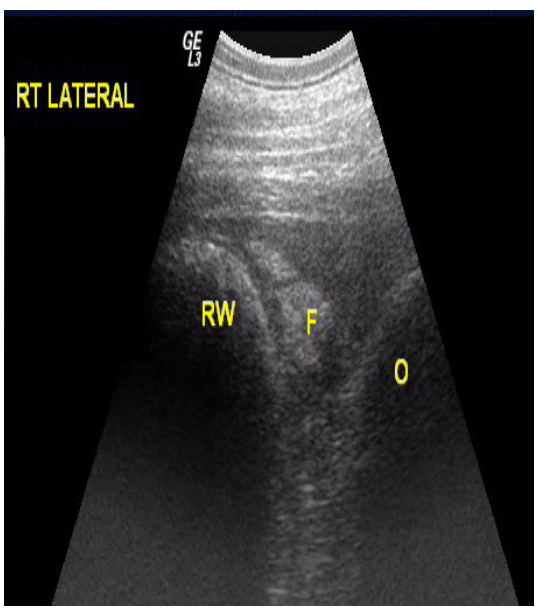
from the right lateral window of reticulum which however, was seen in 63.63% (n=7/11) healthy cattle. In TRP buffaloes the liver was visualized in 71.43% (n=5) animals which otherwise was visualized in 54.54% (n=6/11) healthy buffalo from this window. Though no reference could be found for this finding but it was thought that it might be due to the shrinking of liver in anorectic cattle or the increase in thickness of the reticular wall or the space occupying peri-reticular effusions which might had caused the liver to disappear from the 6th ICS where it was normally seen dorso-lateral to reticulum in healthy bovine. And since the peri-reticular effusions were more in cattle compared to buffaloes from this window, the liver was visualized in less number of cattle compared to buffaloes on the same position.

The reticular wall contour was smooth in 33.33% and 28.57% TRP (completely penetrating foreign body) affected cattle and buffalo respectively compared to 63.64% and 90.90% in healthy cattle and buffalo respectively. Corrugated contour and uneven surface of reticular wall had also been reported (Braun, 2005; Kumar *et al*., 2007; Braun, 2009; Abdelaal *et al*., 2009; Gouda, 2015; Abdelaal *et al*., 2016; Kumar *et al*., 2018) in bovine suffering from TRP.

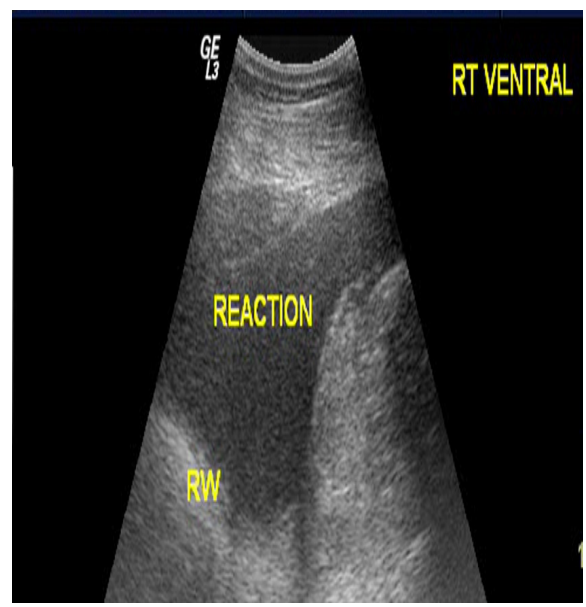
Right ventral ultrasound window

One buffalo was not scanned from right ventral window as there was edema at this site and ultrasonographic visibility was poor, so only 6 buffaloes were included. No significant statistical difference was recorded between the objective parameters TRP affected (with completely penetrating foreign body) and healthy cattle and buffaloes from this window.

The diaphragmatic abscess found



7a



7b

Figure 7. Ultrasonogram showing echogenic deposits (7a) and Anechoic fluid (7b) in the peri-reticular space.

Table 3. Ultrasonographic features of completely penetrating foreign bodies as confirmed on rumenotomy in cattle and buffaloes.

S. No	Parameters	Cattle (N=9)				Buffaloes (n=7)			
		Rt lateral	Rt ventral	Lt lateral	Lt ventral	Rt lateral	Rt ventral	Lt lateral	Lt ventral
1	**Reticular wall thickness**	1.21 ± 0.5	0.77 ± 0.3	1.42 ± 0.64	1.04 ±0.38	1.3 ± 0.40	0.74 ± 0.30	1.38 ± 0.88	0.85 ± 0.64
2	**Depth of phase I motility**	5.29 ± 2.5	5.49± 3.63	3.7 ± 1.64	3.29 ± 1.43	4.19 ± 1.87	3.25 ± 1.77	3.56 ± 1.86	4.86 ± 1.96
3	**Depth in phase II motility**	6.13 ± 2.22	5.7 ± 3.02	5.11 ± 1.41	6.3 ± 2.53	6.08 ± 3.66	4.95 ± 3.61	6.27 ± 2.76	5.39 ± 2.29
4	**Depth in phase III motility**	None	None	7.33	None	None	None	None	None
5	**Liver /spleen thickness**	1.43 ± 0.56	One case=3.2	1.77 ± 1.12	None	2.17 ± 0.88	None	3.04 ± 1.59	None
6	**Depth of reticulum**	5.27 ± 1.9	5.12 ± 2.08	3.73 ± 1.46	4.99 ± 2.03	4.96 ± 2.76	None	5.06 ± 3.95	Not measurable
7	**Reticular wall contour**								
	Smooth	4/9=44.44%	4/9= 44.44%	4/9= 44.44%	6/9= 66.66%	2/7=28.57%	100%	3/7=42.85%	4/7=57.14%
	Wavy	5/9=55.55%	5/9=55.55%	5/9=55.55%	3/9=33.33%	5/7=71.43%	0	4/7=57.14%	3/7=42.85%
8	**Reticular motility**								
	No motility	1/9=11.11%	3/9=33.33%	1	**1**	0	2/6=40%	**1**	**1**
	Monophasic	1	**0**	1	1	3/7=42.86%	0	2/7=28.57%	2/7=28.57%
	Biphasic	3/9=33.33%	6/9=66.67%	0	6/9=66.67%	4/7=57.14%	3/5=60%	4/7=57.14%	4/7=57.14%
	Folding	4/9=44.44%	0	5/9=55.55%	1	0	0	0	0
9	**Peri-reticular effusions/echogenic masses/abscess**	4/9=44.44% One abscess in liver	4/9=44.44% Abscess=1	1/9=11.11%	7/9=77.77%	2/7=28.57% (one mild, one thick masses)	5/6=83.33%	2/7=28.57% (one mild, one masses)	4/7=57.14%
10	**Adhesions**	100% cases	100% cases	100% cases	100% cases	5/7=71.42%	5/7=71.42%	5/7=71.42%	5/7=71.42%

on rumenotomy in a cow was visible in this parasternal view while the nodule was not seen. The number of cattle with biphasic motility were more (6/9=66.66%) compared to the right lateral window where it was in 33.33%, and there was no cattle with folding type motility as observed from the right lateral window. This may be correlated that the folding type motility is a version of biphasic motility only. In buffaloes only 66.66% animals (n=4) showed reticular motility (3 biphasic and 1 monophasic), which was less compared to right lateral window, suggesting that the reticulum from right ventral window was more affected in TRP in buffaloes. From this window, 33.33% cattle (n=3) and 40% buffaloes (n=2) did not showed any reticular motility.

Peri-reticular effusions were recorded in 44.44% (n=4) cattle and 83.33% (n=5) buffaloes from the right ventral window. The effusions varied from anechoic to echogenic masses in buffaloes (1.62 to 4.88 cm) and in cattle (upto 5.76 cm). More number of buffaloes showed peri-reticular effusions from this window compared to that from right lateral window; however, it was same for the cattle. Suggesting, that the right ventral aspect of reticulum is more affected regarding peri-reticular effusions in buffaloes suffering from completely penetrating foreign body compared to right lateral.

On ultrasound from the right ventral window, it was observed that the reticulum may be pushed cranially due to the enlarged abomasum or omasum and may be lifted dorsally due to the presence of peri-reticular effusions or abscess. Displacement of the reticulum dorsally i.e several centimetres from the peritoneum by the presence of inflammatory debris and visible echogenic peri reticular cavitations and other structures had been reported (Streeter and Strep, 2007; Ramprabhu *et al*., 2003).

The reticular wall pattern was smooth in 44.44% TRP cattle with completely penetrating foreign body compared to buffalo where it was smooth in 100% buffaloes (n=6). Compared to right lateral window from right ventral window, the reticular wall pattern was smoother in buffaloes.

Left lateral ultrasound window

Reticular motility (monophasic, biphasic or folding) was recorded in 88.88% TRP cattle (n=8) and 85.71% buffaloes (n=6) from the left lateral window, which was similar to the right lateral window. Folding type of reticular motility was recorded in 55.55% (n=5) of TRP cattle however, no TRP buffalo showed folding motility from this window. Folding type motility was otherwise also recorded in healthy cattle from the left lateral window. In both the species, one bovine did not show any motility from this window.

Peri-reticular effusions were recorded in less number of bovine from left lateral window (11.11% cattle and 28.57% buffalo). Suggesting the fact that left lateral aspect of reticulum was less affected in TRP with completely penetrating foreign body. Braun (2005; 2009) reported that in TRP cattle most frequent morphological changes are seen in the area of caudo ventral reticular wall followed by cranio-dorsal blind sac of rumen.

The percentage of reticular wall having smooth (nearly 42%) and wavy pattern was similar in cattle and buffaloes from this window.

Left ventral ultrasound window

The reticular wall thickness was recorded to be significantly (P=0.036) more in completely penetrating TRP cattle compared to healthy cattle from the left ventral window.

The reticular wall was smooth in 66.66% cattle (n=6) and 57.14% buffaloes which was better

Table 4. Ultrasonographic features of partially penetrating foreign bodies as confirmed on rumenotomy in cattle and buffaloes.

S. No	Parameters	Cattle (N=9)				Buffaloes (n=7)			
		Rt lateral	Rt ventral	Lt lateral	Lt ventral	Rt lateral	Rt ventral	Lt lateral	Lt ventral
1	**Reticular wall thickness**	0.86 ± 0.26	0.91 ± 0.48	1.08 ± 0.51	0.74 ± 0.39	1.2 ± 0.41	1.14 ± 0.7	1.43 ± 0.61	0.97 ± 0.25
2	**Depth of phase I motility**	2.48 ± 1.32	3.32 ± 2.10	3.53 ± 2.09	3.05 ± 0.81	4.11 ± 2.72	5.78 ± 0.98	3.55 ± 1.32	6.44 ± 2.67
3	**Depth in phase II motility**	2.68 ± 1.32	5.63 ± 3.25	4.34 ± 3.09	5.13 ± 0.59	5.15 ± 3.32	8.59 ± 3.85	5.83 ± 0.89	6.02 ± 3.96
4	**Depth in phase III motility**	2.38 ± 1.95	None	None	1.47	None	None	7.31	
5	**Liver /spleen thickness**	2.49 ± 1.75	One case=6.75	2.9 ± 1.74	3.57	2.45 ± 1.47	None	3.31 ± 1.52	3.85 ± 0.66
6	**Depth of reticulum**	4.51 ± 3.22	8.41 ± 2.95	5.31 ± 1.73	6.36 ± 2.0	5.05 ± 0.55	5.41 ± 1.48	5.76 ± 1.46	8.07 ± 2.68
7	**Reticular wall pattern**								
	Smooth	5/8=62.5%	3/6= 50.0%	5/7= 71.43%	6/9= 66.66%	5/6=83.33%	6/7=85.71%	3/6=50.0%	5/6=83.33%
	Wavy	3/8=37.5%	3/6=50.0%	2/7=28.57%	3/9=33.33%	1	1	3/6=50.0%	1
	Not recordable	1	0	0	0	0	0	0	0
8	**Reticular motility**								
	No motility	2/8=25.0%	0	3/9=33.33%	1	2/6=33.33%	1/5=20%	1	1
	Monophasic	0	0	0	0	1/6=16.66%	0	1	1
	Biphasic	3/8=37.5%	5/5=100%	4/9=44.44%	6/9=66.67%	3/6=50.00%	4/5=80%	2	4/6=66.67%
	Triphasic	3/8=37.5%	0	0	1	0	0	1	0
	Folding	0	0	2/9=22.22%	1	0	0	1	0
	Not recordable	0	4	0	0	0	0	0	0
9	**Peri-reticular effusions/echogenic masses/abscess**	2/9=22.22% One abscess pushing reticulum deep	6/9=66.66%	2/9=22.22% (one mild, one large pocket)	6/9=66.66%	none	6/7=85.71%	none	3/6=50.0%
10	**Adhesions**	5/8=62.5%	5/8=62.5%	5/8=62.5%	5/8=62.5%	3/6=50.0%	3/6=50.0%	3/6=50.0%	3/6=50.0%

than that recorded from other windows except the right ventral window where it was smooth in 100% buffaloes.

The peri-reticular reaction in the form of anechoic or echogenic fluid was evident in 77.77% TRP cattle on the left ventral window, which was highest compared to other 3 windows. However, in 57.14% buffaloes showed reaction. The column of effusions was maximum seen up to 6.15 cm in cattle and 9.12 cm in buffalo. Suggesting that more percent cattle showed per-reticular effusions on the left ventral aspect in case of completely penetrating foreign body compared to buffalo which otherwise showed more percentage from right ventral aspect. Though the column of effusions was more in buffalo compared to cattle from this window.

2) Ultrasonographic findings of partially penetrating foreign bodies in cattle and buffaloes (Table 4)

The average age, body weight and width of cattle and buffaloes with partially penetrating foreign bodies were 4.77±1.64 years, 352.22±61.49 kgs, 33.33±6.10 cms and 5.43±1.39 years, 459.14±138.85 kgs, 33.0±7.70 cms respectively.

No significant statistical difference was recorded between the completely penetrating and partially penetrating and healthy cattle from the right side ultrasound among the objective parameters. The reticular wall pattern was recorded to be smooth in more percentage of TRP cattle and buffaloes having partially penetrating foreign body compared to bovine having completely penetrating foreign body.Reticular motility was recorded in more number of TRP cattle having partially penetrating foreign body compared to those having completely penetrating foreign body from all the windows, and with more variety of motility i.e. monophasic, biphasic, triphasic and folding type. Absence of reticular motility was also recorded in few cattle. However, in buffalo the motility pattern was almost similar to that of those having completely penetrating foreign body from all the windows.

Only 22.22% cattle and none of the buffaloes suffering from partially penetrating foreign body showed reticular effusions from both the lateral windows. However, 66.66% of TRP cattle having partially penetrating foreign body showed effusions on the ventral aspect of the reticulum from both sides, while in buffalo 85.71% animal showed effusions from the right ventral window and 50% from left ventral. Suggesting that the peri-reticular effusions were in more number of buffaloes having partially penetrating foreign body compared to completely penetrating foreign body from the right ventral window.

3) Ultrasonographic findings of non- penetrating foreign bodies in cattle (n=3) and buffaloes (n=1)

Despite non-penetrating foreign bodies, the per-reticular effusions were seen on the ventral aspect of reticulum from both sides, although in less quantity in cattle. The wall varied from wavy to smooth, but all the cattle had biphasic motility.

In buffalo, there was one case with non-penetrating foreign body, where ultrasound was done and the buffalo has a cranio-ventral reticular abscess. The reticular wall was smooth from all sides however, mild reaction was seen on the peri-reticular region from the left lateral window and the abscess was seen from right and left ventral aspect.

From the above study the following conclusions were drawn:

1. The reticular wall thickness up to 0.82 cm may be considered normal in bovine; although,

it may vary in different regions of reticulum.

2. Objective parameters related to reticulum are not statistically significantly different in TRP cattle and buffaloes compared to healthy cattle and buffaloes from all the four windows.

3. In subjective parameters, the reticular wall pattern changes to wavy from smooth in TRP cattle. While it was mostly smooth in buffalo. In healthy buffalo also the reticular wall is mostly smooth from all the four windows while it is not so in cattle confirming the fact that the wavy nature of the wall is not related to foreign body.

4. The peri-reticular effusions are maximum seen from the left ventral window in cattle and right ventral in buffalo in completely and partially penetrating foreign bodies. Effusions may also be present in non-penetrating foreign body in cattle.

5. The reticular motility persists in maximum number of bovine despite adhesions present on rumenotomy and that the cattle showed more adhesions for partially penetrating foreign bodies, compared to buffalo.

From the above study, variations in the ultrasonographic appearance of reticulum were found between the healthy cattle and buffalo. Amount of effusions was the only criterion which may be used to assess the penetrating status of a foreign body in bovine.

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REFERENCES

Abdelaal, A.M., M. Floeck, S.Et. Maghawry and W. Baumgartner. 2009. Clinical and ultrasonographic differences between cattle and buffaloes with various sequele of traumatic reticuloperitonitis. *Vet. Med. Czech*., **54**(9): 399-406.

Abdelaal, A.M. and M. Floeck. 2015. Clinical and sonographical findings in buffaloes (*Bubalus bubalis*) with traumatic reticulo-pertonitis. *Vet. Arhiv*., **85**(1): 1-9.

Abdelaal, A.M., M.B. Mostafa, M. Abu-Seida, O.S. Al-Abbadi and S.F. Abbas. 2016. Ultrasonographic findings in hardware diseased buffaloes (*Bubalus bubalis*). *Research Journal of Pharmaceutical Biological and Chemical Sciences*, **7**(5): 1644-1649.

Aref, N.M. and M.H.A. Hakiem. 2013. Clinical and diagnostic methods for evaluation of sharp foreign body syndrome in buffaloes. *Vet. World*, **6**: 586-591.

Braun, U. 2005. Ultrasound as a decision-making tool in abdominal surgery in cows. *Vet. Clin. Am N. Food A*., **21**: 33-53.

Braun, U. 2009. Traumatic pericarditis in cattle: Clinical, radiographic and ultrasonographic findings. *Vet. J*., **182**: 176-186.

Braun, U. and S. Rauch. 2008. Ultrasonographic evaluation of reticular motility during rest, eating, rumination and stress in 30 healthy cows. *Vet. Rec*., **163**(19): 571-574.

Braun, U., M. Gotz and O. Marmier. 1993. Ultrasonographic findings in cows with traumatic reticuloperitonitis. *Vet. Rec*., **133**: 416-422.

Chaudhari, K.S., M.G. Thorat, G.U. Yadav, J.B. Mulani, A.A. Suryawanshi and S.S. Ingale.

2009. Role of Radiological examination in diagnosis of foreign body in bovines. *Vet. World*, **2**(9): 339.

Gouda, S.M. 2015. Ultrasonographic identification of abdominal and thoracic lesions resulting from foreign body syndrome in buffaloes. *Research Journal for Veterinary Practitioners*, **3**(2): 41-46.

Kumar, A., S.K. Mahajan, V. Sangwan and A. Anand. 2018. Diagnosis and retrieval of extra reticular metallic foreign body in a buffalo. *Buffalo Bull.*, **37**(2): 273-278.

Kumar, M., J. Mohindroo, A. Kumar and S.S. Singh. 2007. Ultrasonographic diagnosis of reticulophrenic adhesions in bovines. *Indian Journal of Veterinary Surgery*, **28**(2): 117-119.

Makhdoomi, S.M., V. Sangwan and A. Kumar. 2018. Radiographic prediction of metallic foreign body penetration in the reticulum of cows and buffaloes. *Vet. World*, **11**(4): 488-496.

Omidi, A. 2008. Less common complication of traumatic reticulitis in cattle: Abscess on left Thoracic Wall. *Asian J. Anim. Vet. Adv.*, **3**(5): 381-385.

Partington, B.P. and D. Biller. 1991. Radiography of the vovine cranio ventral abdomen. *Vet. Radiol. Ultrasoun.*, **32**(4): 155-168.

Ramprabhu, R., P. Dhanapalan and S. Prathaban. 2003. Comparative efficacy of diagnostic tests in the diagnosis of Traumatic Reticuloperitonitis and allied syndrome in cattle. *Isr. J. Vet. Med.*, **58**: 2-3.

Sangwan, V., S.M. Makhdoomi and A. Kumar. 2018. Surgical retrieval of embedded metallic foreign bodies from the reticulum in bovine. *Indian Vet. J.*, **95**(11): 28-31.

Singh, S., J. Mohindroo, A. Kumar and V. Sangwan. 2013. B+M mode ultrasonography in evaluating reticular health in cows and buffaloes. *Indian Journal of Veterinary Research*, **22**: 52-58.

Streeter, R.N. and D.L. Step. 2007. Diagnostic ultrasonography in ruminants. *Vet. Clin. N. Am. Food Anim. Prac.*, **23**: 541-574.