Turkish Journal of Veterinary and Animal Sciences

http://journals.tubitak.gov.tr/veterinary/

Research Article

Turk J Vet Anim Sci
(2017) 41: 323-331

doi:10.3906/vet-1604-94

# Comparison of four ultrasonographic approaches for the diagnosis of acquired reticular diaphragmatic hernia in Bovidae

**Ashwani KUMAR[1,*], Vandana SANGWAN[2], Jitender MOHINDROO[1], Narinder Singh SAINI[1], Simrat Sagar SINGH[1]**

[1]Department of Veterinary Surgery and Radiology, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, India

[2]Department of Teaching Veterinary Clinical Complex, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, India

**Received:** 28.04.2016 • **Accepted/Published Online:** 01.03.2017 • **Final Version:** 12.06.2017

**Abstract:** The aim of this study was to look at four ultrasonographic approaches that diagnose acquired reticular diaphragmatic hernia (RDH) using either left or right caudal thoracic approaches (4th/5th intercostal space) and compare them to those made more cranially (1st/2nd intercostal space). Each sonographic observation was made in 27 unsedated, standing animals (22 buffaloes and 5 cattle) that were surgically confirmed for RDH. Using the right caudal thoracic approach, the herniated reticulum was seen as medial to the thoracic wall at a depth of 3–5 cm and adjacent to the cardiac silhouette. With the left caudal thoracic approach, the herniated reticulum was seen at a depth of 10–15 cm beyond the heart, which acted as a useful acoustic window. Compared to the nonherniated reticulum, the herniated reticulum had subjectively reduced amplitude or no contractions. The right cranial thoracic approach detected a significantly ($P < 0.01$) larger herniation (22.60 ± 1.65 cm) than that of the smaller hernia (14.09 ± 0.82 cm) when measured with radiographs. However, the left cranial thoracic approach was able to diagnose RDH in one buffalo with extensive herniation. In conclusion, RDH was consistently demonstrated ultrasonographically using caudal thoracic approaches, whereas the cranial thoracic approaches were only of value in Bovidae with extensive reticular herniation.

**Key words:** Buffalo, cattle, diaphragmatic hernia, reticulum, radiography, ultrasonography

## 1. Introduction

Diaphragmatic herniation is defined as a protrusion of abdominal organs into the thoracic cavity through a tear in the diaphragm (1). The subfamily Bovidae is a diverse group of mammals and includes domestic cattle, water buffaloes, African buffaloes, bison, yaks, and antelopes. Diaphragmatic hernia has frequently been reported in water buffaloes (*Bubalus bubalis*) (2–4) but rarely in purebred (*Bos indicus*) (5–7) and crossbred cattle (*Bos indicus* × *Bos taurus*) (8,9), where it may be congenital (5) or acquired (1,3,4,6,7,9). As the reticulum is the most commonly herniated organ (1,3,4,9), the condition has been referred to as reticular diaphragmatic hernia (RDH) (10,11). The inherent weakness of the diaphragm, its progressive weakening due to reticuloperitonitis, and other conditions that increase intraabdominal pressure such as ruminal tympany, a violent fall, advanced pregnancy, the calving process, chronic cough, and straining could be exacerbating factors for RDH (1,2). The diagnosis of RDH using ultrasonography was initially reported in cows (9) and buffaloes (11) where the diagnostic criterion was the detection of the herniated reticulum in sonographic images made at the right 4th and/or 5th intercostal space (ICS). It was later observed in normal adult cows that the cranial part of the reticulum was detected at the right 5th ICS (irrespective of pregnancy) and in late-pregnant buffaloes (12) or in animals with extremely distended abdomens (13). In other reports, the detection of the herniated reticulum at the right 4th ICS was a reliable criterion in the diagnosis of RDH in cows and buffaloes, irrespective of pregnancy (12); however, a small RDH could not be demonstrated in these cases (14). The effect of RDH on the ultrasonographic appearance of the adjacent thoracic structures (lungs and heart) has also recently been described (15).

To access the right 4th ICS for ultrasonographic examination, the right thoracic limb needs to be pulled cranially (11), and such a maneuver may induce pain in animals with RDH, preventing ultrasonographic access to this area. Moreover, in obese animals or those with well-developed thoracic limb musculature, it may not be possible to move the thoracic limb sufficiently far enough

* Correspondence: drashwanikumar@rediffmail.com

cranially to permit sonographic access to the right 4th ICS. Additional sonographic approaches or windows that could expose RDH would be useful, particularly if clinical accessibility may only be from one side. Our hypothesis was that the ultrasonographic diagnosis of RDH could be made equally well from either side of the thorax, irrespective of the size of the RDH, using the caudal or cranial approach in crossbred cattle and buffaloes. We also aimed to study the pathological changes and motility of the herniated part of the reticulum compared to its nonherniated portion.

**2. Materials and methods**

This study of RDH included 27 female nongravid Bovidae animals: 22 buffaloes (Murrah and Nili-Ravi breeds) and 5 crossbred cattle. The mean age and standard error was 5.53 ± 0.4 years (a range of 3–8 years), and the body weight was 390 ± 21.2 kg (a range of 200–480 kg). The study period was 1 year (January to December 2014). Each animal had a history of 1 to 4 weeks of illness with clinical signs of a partial alimentary tract obstruction (intermittent anorexia, chronic tympany, suspended rumination, and decreased fecal production).

The presence of RDH was confirmed by radiography. A left to right lateral radiograph of the caudal thoracic region was taken (90–100 kVp, 50–60 mAS at a focus-film distance of 90–100 cm with an 800 mA X-ray machine; Siemens, Mumbai, India) in nonsedated animals positioned in right lateral recumbency. The X-ray beam was centered on the 6th ICS and 17.8–20.3 cm dorsal to the sternum (10,13). The images were processed using a computed radiography system (Kodak, Chandigarh, India). In each image, the size of the RDH was estimated (cm) by measuring the craniocaudal distance of the circular opacity corresponding to the herniated reticulum in the thoracic cavity. The diameter was measured from the diaphragm to the cranial-most part of the herniated reticulum. The measurements (mean ± standard error) were divided into two groups: those animals in which a cranial thoracic ultrasonographic approach confirmed the presence of RDH and another group in which the same ultrasonographic examination did not demonstrate RDH. Student's t-test was used to determine the significance of any differences between the data sets (SPSS 16.0; SPSS Inc., Chicago, USA).

In preparation for ultrasonography, hair was clipped from the ventral 3rd of both lateral sides of the thorax at the level of the 4th and 5th ICS (the caudal thoracic approach), the 1st and 2nd ICS (the cranial thoracic approach), or the 6th and 7th ICS for an abdominal approach to the nonherniated reticulum (11). Ultrasonography was performed on the nonsedated, standing animal with the ipsilateral thoracic limb pulled cranially for the caudal thoracic approach (11) while a normal, standing posture was used for the cranial thoracic and abdominal approaches. For the cranial thoracic approach, the transducer was placed cranially to the limb for scanning through the 1st and 2nd ICS. The skin was cleaned with soap and an ultrasound gel was applied. B-mode and B+M-mode images of the herniated reticulum were made with a 2–5 MHz multifrequency curvilinear array transducer (Wipro Logiq 3 Expert Ultrasound Machine, General Electronics Healthcare, Bangalore, India). The transducer was moved dorsoventrally at each intercostal space to visualize, in particular, the herniated and nonherniated abdominal reticulum and its contractions, as well as its relationship with the lungs and heart. The images were continuously recorded on the hard drive of the ultrasound machine. The amplitude of the contractions of the herniated reticulum within the thoracic cavity was subjectively compared to that of the nonherniated part of the reticulum.

One to 3 days after the ultrasound examination, all of the animals were fasted and a left-sided laparorumenotomy (Stage I) was done to confirm the presence of RDH. The surgery was undertaken in unsedated, standing animals using a paravertebral nerve block or local infiltration analgesia with 2% lignocaine (Neon Laboratories Ltd., Mumbai, India). The extent and site of herniation was assessed, as well as the presence of reticular adhesions. An observation of whether there was complete emptying of the rumen and reticular contents and whether there were ruminal or reticular foreign bodies was also made (1,3). Each animal was put under general anesthesia 24 h later (midazolam at 0.2 mg/kg + butorphanol 0.025 mg/kg + ketamine 4 mg/kg + 2% isoflurane), and the RDH was repaired via a cranial midline approach (Stage II) (16).

**3. Results**

Ultrasonographic diagnosis of RDH in each animal was confirmed by laparorumenotomy, and a tear in the right ventral 3rd of the diaphragm was located. Thirty to 60% of the reticulum was herniated in the thorax. Metallic linear foreign bodies and other foreign objects (round, oval, or tiny metallic pieces; small stones and sand particles) were removed from the herniated reticulum. In all of the animals, adhesions were present between the herniated reticulum and the torn edges of the diaphragm and/or the pleura; however, neither the foreign bodies nor the adhesions were observed sonographically. In the present study, 23 out of 27 (85.2%) of the animals survived whereas 4 animals (3 buffalo and one cow) died intraoperatively or during the recovery period.

All of the animals were radiographically diagnosed with RDH prior to ultrasonographic investigation through various thoracic windows. These radiographic features are summarized in Table 1. Radiographic features of the RDHs observed included abnormal opacity of the soft

**Table 1.** Radiographic features of reticular diaphragmatic hernia (RDH) in Bovidae.

| Radiographic features | Number of bovines | Percent (%) |
|---|---|---|
| Number of buffaloes positive for RDH | 22 | 81.48 |
| Number of cattle positive for RDH | 5 | 18.51 |
| Soft tissue opacity cranial to the diaphragm | 25 | 92.59 |
| Honeycomb-like opacity cranial to the diaphragm | 2 | 7.41 |
| Partial loss of the diaphragm line | 7 | 25.92 |
| Complete loss of the diaphragm line | 20 | 74.08 |
| Craniocaudal size of the RDH (mean ± SE) | 17.87 ± 1.19 cm | - |

tissue (n = 25) or a honeycomb-like pattern (n = 2) with sharp and blunt metallic foreign bodies present from the cranial region to the diaphragm with partial (n = 7) or complete (n = 20) loss of the diaphragmatic line. The mean craniocaudal size of the herniated reticulum was 17.87 ± 1.19 cm (a range of 9.0–32.8 cm).

In the present study, using the abdominal approach (from the 6th and 7th ICS), the reticulum was seen as an echogenic structure with a smooth contour and biphasic motility (Figure 1). Comparative ultrasonographic features of RDH using various approaches are depicted in Table 2.

Ultrasonography using the right caudal thoracic approach showed the right lung as dorsally displaced by the ventrally located herniated reticulum that extended medially from the right thoracic wall to a depth of 3–5 cm (Figure 2). The wall of the reticulum was consistently identified in all animals as a 10-mm-thick echogenic structure with a smooth contour with the exception of 10 Bovidae (7 buffaloes and 3 cows) with an irregular contour of the herniated reticulum. Among these, only 3 (2 cows and 1 buffalo) also had effusion and fibrin surrounding the herniated reticulum. In 21 animals (16 buffaloes and

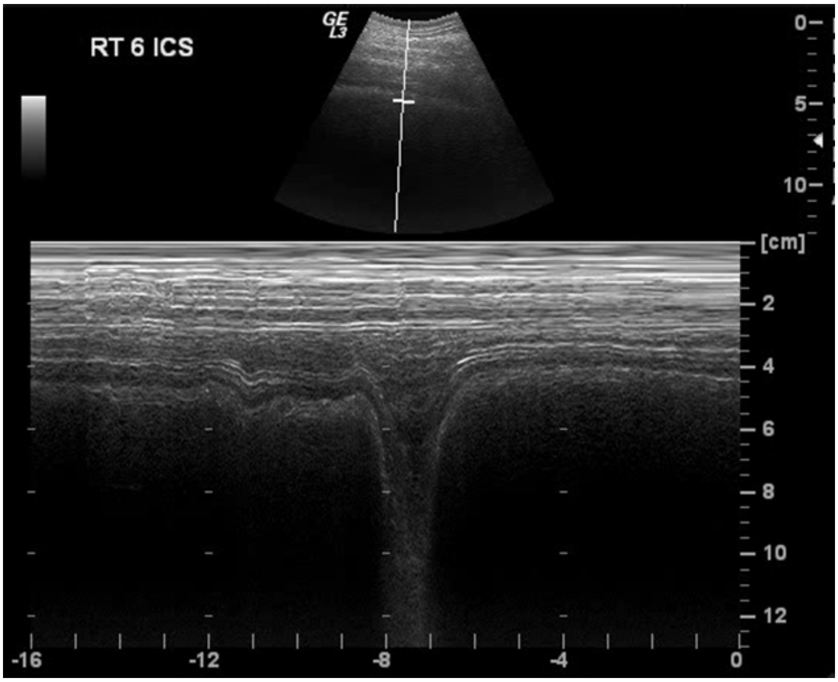


**Figure 1.** B- and M-mode ultrasonographic image of a buffalo reticulum using the abdominal approach at the right 6th ICS. In the B-mode image, the M-mode cursor is located in the lumen of the reticulum. The M-mode image shows a relatively high amplitude biphasic reticular contraction (compare with Figure 2). Depth (cm) is displayed on the right side of each image and time (s) is shown below the M-mode image.

**Table 2.** A comparative depiction of ultrasonographic (USG) features of RDH using various approaches.

| USG features of RDH | Right caudal | Left caudal | Right cranial | Left cranial |
|---|---|---|---|---|
| Number of cases diagnosed | 27 | 27 | 12 | 1 |
| Craniocaudal size of RDH on radiographs (cm) | 14.09 ± 0.82 | 14.09 ± 0.82 | 22.60 ± 1.65 | 30.1 ± 0 |
| Position of lung | Displaced dorsally | No change | No change | No change |
| Depth of reticulum (cm) | 3–5 | 10–15 | 7–10 | 8 |
| Contour of reticulum | | | | |
| Smooth | 17 (15B + 2C) | 17 (15B + 2C) | 12 (10B + 2C) | 1 (B) |
| Irregular | 10 (7B + 3C) | 10 (7B + 3C) | 0 | 0 |
| Effusions around herniated reticulum | 3 (1B + 2C) | 4 (2B + 2C) | 0 | 0 |
| Reticular motility | | | | |
| Reduced | 21 (16B + 5C) | 19 (15B + 4C) | 8 (7B + 1C) | 1 (B) |
| Amotile | 6 (B) | 8 (7B + 1C) | 4 (3B + 1C) | 0 |
| Obscuring of heart | | | | |
| Partial | 15 (11B + 4C) | 0 | 0 | 0 |
| Complete | 12 (11B + 1C) | 0 | 0 | 0 |
| Heart-related pulsatility in herniated reticulum | Present | Present | Present | Present |

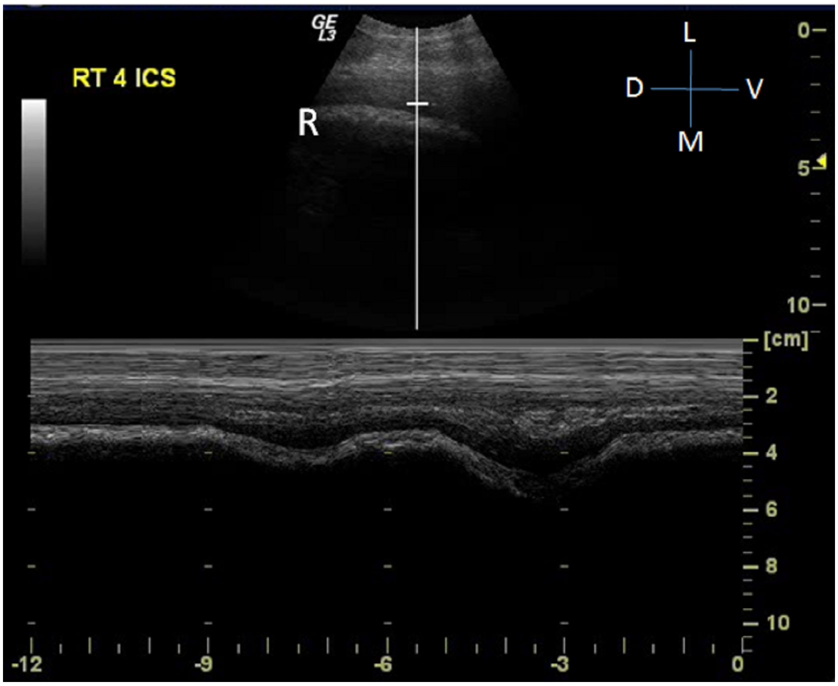


**Figure 2.** B- and M-mode ultrasonographic image of a buffalo reticulum using the right caudal approach at the 4th ICS. In the B-mode image, the M-mode cursor is located in the lumen of the herniated reticulum. Note that the heart is not detectable in the image as it has been completely obscured by the herniated reticulum. The M-mode image shows a reduction in the amplitude of the biphasic reticular contraction (compare with Figure 1 with the same orientation). Depth (cm) is displayed on the right side of each image and time (s) is shown below the M-mode image. L = Lateral, M = medial, D = dorsal, V = ventral, R = reticulum.

5 cattle), the monophasic or biphasic contractions of the reticulum were qualitatively of reduced amplitude (in comparison to observations made at the 6th and 7th ICS, shown in Figure 1). In the remaining 6 buffaloes, the herniated reticulum-like structure was amotile. In animals with amotile reticulum-like structures, a tentative diagnosis of RDH was made based on both radiographic and ultrasonographic findings, which was later confirmed during surgery. The herniated reticulum partially (n = 15; 11 buffaloes and 4 cattle) or completely (n = 12; 11 buffaloes and 1 cow; Figure 2) obscured the heart, which became visible when the reticulum contracted. It was also noted that the herniated reticulum was displaced lateromedially in a pulsatile fashion in association with the cardiac cycle.

Ultrasonography from the left caudal thoracic approach revealed a normal left-ventral lung edge but a right-sided compression of the heart by the echogenic herniated reticulum with a smooth contour, which was consistently detected on the far side of the heart at a depth of around 10–15 cm in all animals (Figure 3). In 10 Bovidae (7 buffaloes and 3 cows) with irregular herniated reticular walls, only 4 (2 cows and 2 buffaloes) showed surrounding fibrin and effusion (Figure 4). Reticular motility could only be seen in 19 animals (15 buffaloes and 4 cattle), and it was amotile in the remaining animals. Cardiac-related pulsatility of the reticulum was also seen from the left side.

The right cranial thoracic sonographic approach showed the herniated reticulum with a smooth contour adjacent to the right thoracic wall in 12 animals (10 buffaloes and 2 cattle; Figure 5), and, of these, reticular contractions were only recorded in 8 animals (7 buffaloes and 1 cow). Neither an irregular outline nor any associated pathological changes around the herniated reticulum could be demonstrated in any of the animals. Radiographically, in this group of animals the cranial border of the RDH extended to the level of the cranial cardiac waist (Figure 6). The cranial extension of the hernia was also confirmed during exploratory laparorumenotomy. The left cranial thoracic approach only detected RDH in one buffalo. This animal had a chronic illness and was weak and emaciated. Animals in which the right cranial thoracic approach successfully detected the RDH (n = 12; Figure 6) had significantly ($P < 0.01$) larger herniation in the radiographs (a mean ± standard error of 22.60 ± 1.65 cm and a range of 14.3–32.8 cm) than those in which a smaller hernia was seen radiographically (a mean ± standard error of 14.09 ± 0.82 cm and a range of 9.0–19.0 cm). Smaller hernias were not detected using the left or right cranial thoracic approach (n = 15; Figure 7).

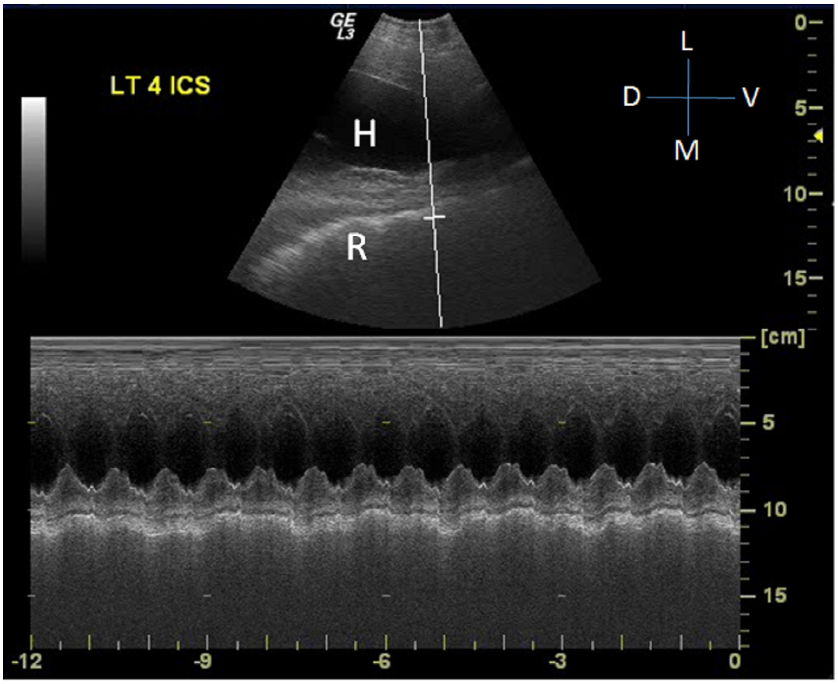


**Figure 3.** B- and M-mode ultrasonographic image of a buffalo reticulum using the left caudal approach at the 4th ICS. In the B-mode image, the M-mode cursor is located in the lumen of the herniated reticulum; note that the heart lies on the lateral aspect of the reticulum. The M-mode image demonstrates the displacement of the amotile reticulum lateromedially with each cardiac cycle. Depth (cm) is displayed on the right side of each image and time (s) is shown below the M-mode image. L = Lateral, M = medial, D = dorsal, V = ventral, H = heart, R = reticulum.

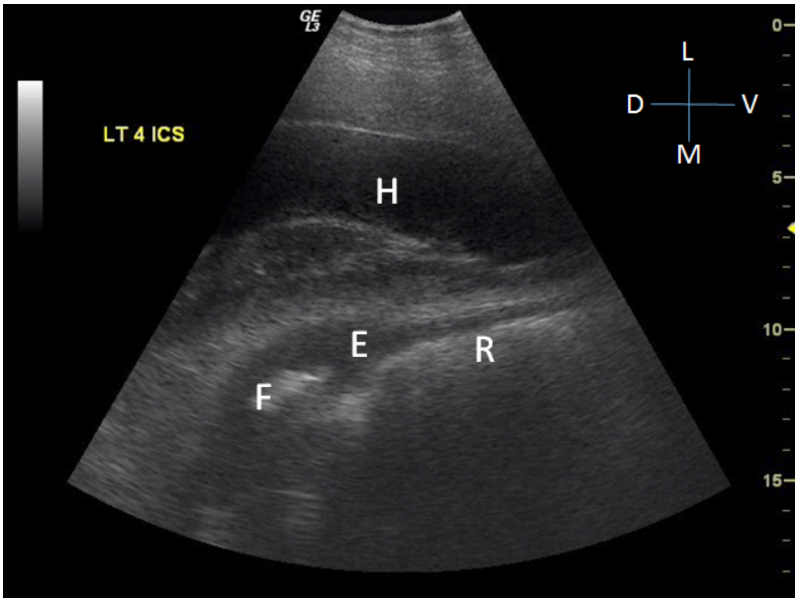


**Figure 4.** B-mode ultrasonographic image of a cow reticulum using the left caudal approach at the 4th ICS showing the irregular reticular wall with surrounding fibrin and effusion; note that the heart lies on the lateral aspect of the reticulum. Depth (cm) is displayed on the right side of each image. L = Lateral, M = medial, D = dorsal, V = ventral, H = heart, R = reticulum, E = effusion, F = fibrin.

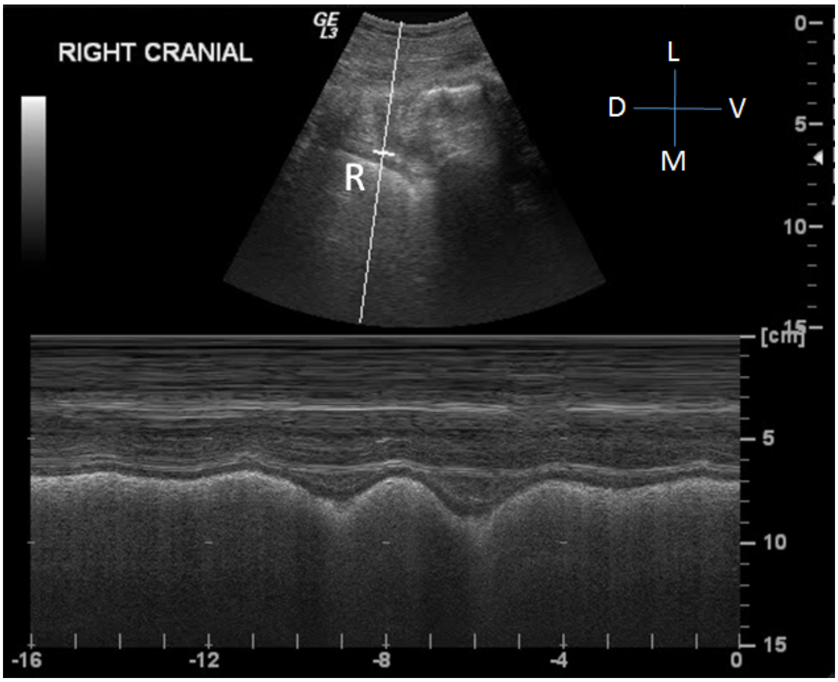


**Figure 5.** B- and M-mode ultrasonographic images of a buffalo reticulum using the right-cranial thoracic approach at the 1st ICS. In the B-mode image, the M-mode cursor is located in the lumen of the herniated reticulum. The M-mode image demonstrates a loss of the biphasic reticular contractions. Depth (cm) is displayed on the right side of each image, and time (s) is shown below the M-mode image. L = Lateral, M = medial, D = dorsal, V = ventral, R = reticulum.

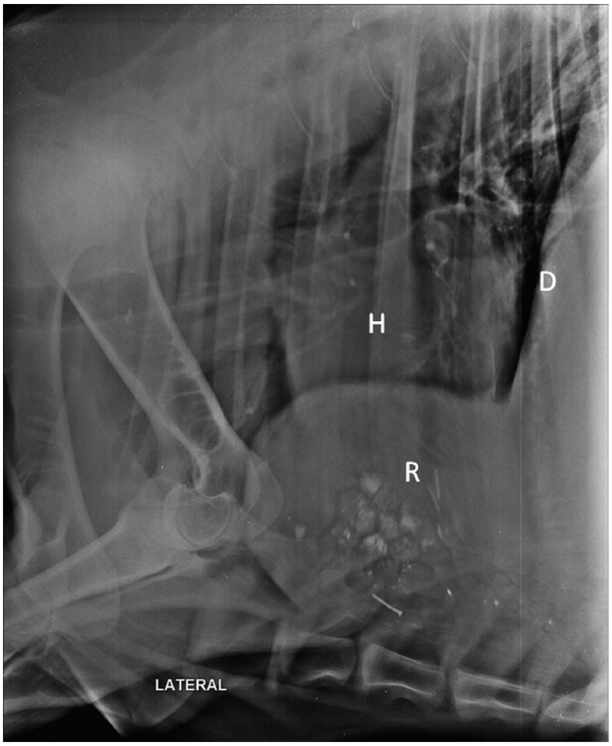


**Figure 6.** Left to right radiograph taken in right lateral recumbency of a buffalo thorax showing extensive herniation of the reticulum (R) containing metallic and mixed-opacity luminal foreign bodies ventrally; the cardiac silhouette (H) and more dorsal parts of the diaphragm (D) are also shown. This hernia could be detected ultrasonographically with a right cranial approach.

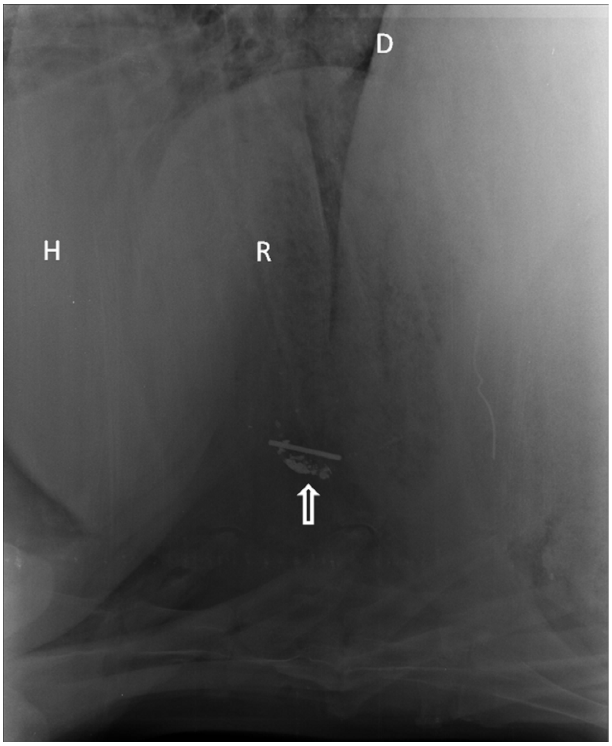


**Figure 7.** Left to right radiograph taken in right-lateral recumbency of a buffalo caudal thorax and cranial abdomen showing moderate herniation of the reticulum containing metallic luminal foreign bodies ventrally (white arrow); the cardiac silhouette and more dorsal parts of the diaphragm can also be seen. D = Diaphragm, H = heart, R = reticulum.

## 4. Discussion

The treatment of RDH requires two-stage surgical management. Laparorumenotomy was useful in the confirmation of the ultrasonographic diagnosis of RDH in all of the animals. Laparorumenotomy is a prerequisite for the surgical management of RDH and helps in the removal of metallic foreign bodies from the reticulum. It is also useful in locating the site of herniation and in emptying forestomach contents (1,3,4) Furthermore, the procedure creates sufficient working space for the suturing of diaphragmatic rent during the 2nd stage of surgery and is necessary to prevent regurgitation in dorsal recumbency during general anesthesia (1,4). Laparorumenotomy is routinely performed in the surgical treatment of RDH in cattle and buffaloes with good results (17,18).

The reticulum is the most commonly herniated organ by diaphragmatic tear in Bovidae (1,3,4,10,17,18) but, on occasion, other abdominal organs may also herniate including the forestomach (6), abomasum (6,19,20), liver (6,17,18,21,22), omasum (6,22), spleen (6,18,22), and small intestines (6). However, in the current study, only reticulum herniations were found, and these were all found on the right side of the diaphragm. Sonography with a 5 MHz transducer in standing animals was easy and safe to perform, and the combination of B- and M-mode observations facilitated the assessment of the patterns of motility of the herniated reticulum and whether the amplitude of their contractions was reduced. The present study observed that compared to a nonherniated reticulum, the herniated reticulum had subjectively reduced amplitude or no contractions. This may be due to the presence of an incarcerated hernia or firm adhesions of the herniated reticulum with surrounding structures that prevented normal contraction or because sometimes no contractions can be sonographically detected. Serosa of the herniated reticulum has been observed to form extensive firm fibrinous adhesions with hernia ring and serofibrinous adhesions with parietal pleura, lungs, and pericardium (3,9,22), and this might affect its contractions. In the present study, all of the animals had adhesions of the herniated reticulum with torn edges of the diaphragm and the pleura, but amotility or reduction in amplitude of the reticular contractions could not be sonographically correlated to the severity of adhesions. Moreover, a smooth or irregular contour of the herniated reticulum was also not correlated to the presence of adhesions. However, the presence of effusion or fibrin in the thoracic cavity adjoining the herniated part of the reticulum may be of some value in predicting surgical outcomes.

In healthy Bovidae, the reticulum is seen ultrasonographically at the level of the elbow at the 6th and 7th ICS (11). Detection of the reticulum using the left and right caudal approaches at the 5th ICS, or cranially to it, is indicative of RDH (9,11,13). Occasionally in normal animals during expiration, in late pregnancy (buffaloes), or in those with abdominal distention, the cranial border of the reticulum caudal and the diaphragmatic interface can be seen at the 5th ICS (12,13). Although sonography at the right 4th ICS was previously described as being the most reliable site for showing RDH (12), it may fail to demonstrate a small hernia, particularly in buffaloes (14). A previous study has shown that sonographic detection of the reticular motility in the thoracic cavity is an important criterion in the diagnosis of RDH (11). However, in the present study, Bovidae with an amotile, thick, echogenic reticulum-like structure in the thoracic cavity were tentatively diagnosed with RDH in combination with radiographic findings, which were later confirmed by left-flank laparorumenotomy.

Previous studies have reported a high prevalence of RDH in the ventral 3rd of the diaphragm at the musculotendinous junction on the right side of the diaphragm (3,4,9,10,12,13,15); however, herniation at either the midventral part or the left side of the diaphragm has also been reported (4,15,18,19,22). One study compared the elastin and hydroxyproline (collagen) content of the tendinous part of the diaphragm between cows and buffaloes and reported marked but nonsignificantly lower values of this in buffaloes (23). Similarly, the right tendinous portion of the buffalo diaphragm had a nonsignificantly lower collagen value compared to the left side (23). The lower elastin and collagen content of the buffalo diaphragm, though statistically nonsignificant, is expected to have less tone and is therefore predisposed to rupture (1). As the herniation in the present study was all right-sided, the reticulum was located between the right thoracic wall and the heart using the right caudal thoracic approach. With the left caudal thoracic approach, it was seen deep in the heart. If a left-sided hernia were present, these observations would be reversed. Although both caudal thoracic approaches demonstrated RDH consistently, the left caudal approach was particularly useful as the heart provided a wide acoustic window through which to locate the herniated reticulum and associated pathological changes in the thoracic cavity. The presence of the herniated reticulum between the heart and the right thoracic wall has been reported to compress and displace the heart towards the left in a cranial manner (22). This has also been found to affect the Doppler parameters of the external jugular vein (24). The intimate association between the heart and the herniated reticulum resulted in a detectable pulsatility of the reticulum in association with the cardiac cycle.

The size of reticular herniation may vary depending on the extent of the tear in the diaphragm and the chronicity of the condition (22). The left and right cranial thoracic sonographic approaches may only have diagnostic value in animals with extensive herniation of the reticulum that extends cranially to the level of the cranial border of the heart or to the thoracic inlet; in animals with mild to moderate herniation, such approaches will not demonstrate the pathology.

Radiography is widely used for the diagnosis of RDH (3,4,9,10,13) but cannot be routinely performed as an outpatient procedure as the animal has to be restrained in lateral recumbency in order to obtain high-quality images of the ventral thoracic region (10). Such recumbent radiography may be contraindicated during advanced pregnancy. Moreover, the radiographic features of RDH may mimic other conditions such as a thoracic abscess, cyst, or tumor. Sonography can be safely performed with the animal standing, can be rapidly performed, and carries no radiation risk. Ultrasonography has been reported as an important diagnostic tool for the investigation of diseases of the digestive system in cattle and for the study of complicated cases of traumatic reticuloperitonitis and its sequelae (25). However, it is not possible to sonographically examine reticular contents, including foreign bodies, because of the presence of gas-mixed contents (26).

In conclusion, RDH was consistently diagnosed sonographically utilizing right and left caudal thoracic approaches with the heart serving as a useful acoustic window in the latter approach. Cranial thoracic approaches were only of value in Bovidae with extensive RDH.

**Acknowledgments**

The authors are thankful to the Indian Council of Agricultural Research for providing financial support for the research project "ICAR 22 – All India Network Program on Diagnostic Imaging and Surgical Conditions in Animals". We are grateful to Dr Andrew Wood of the University of Pennsylvania and Professor Robert Kirberger of the University of Pretoria for giving us advice on the manuscript on behalf of the International Veterinary Radiology Association.

## References


1. Singh J, Fazili MR, Chawla SK, Tayal R, Behl SM. Current status of diaphragmatic hernia in buffaloes with special reference to etiology and treatment: a review. Ind J Vet Surg 2006; 27: 73-79.
2. Singh J, Dhablania DC, Prasad B, Rathor SS. On the etiology of diaphragmatic hernia in buffaloes. Japan J Vet Sc 1980; 42: 89-91.
3. Saini NS, Sobti VK, Mirakhur KK, Singh SS, Singh KI, Bansal PS, Singh P. Bhatia R. Retrospective evaluation of 80 non-surviving buffaloes with diaphragmatic hernia. Vet Rec 2000; 147: 275-276.
4. Saini NS, Sobti VK, Mirakhur KK, Singh SS, Singh KI, Bansal PS, Singh P, Bhatia R. Survivors of diaphragmatic hernia in buffaloes. Ind J Anim Sc 2001; 71: 839-840.
5. Lewis AM. Congenital diaphragmatic hernia in the calf. Vet Rec 1974; 94: 102.
6. Steiner A, Edeid M, Fluckiger M. Diaphragmatic hernia in a cow. Agri Pract 1992; 13: 37-40.
7. Bellavance A, Bonneville-Hebert A, Desrochers A, Fecteau G. Surgical correction of a diaphragmatic hernia in a newborn calf. Can Vet J 2010; 51: 767-769.
8. Singh SS, Mirakhur KK, Singh KI, Sharma SN. Standing thoracotomy and diaphragmatic herniorrhaphy in a cow. Vet Rec 1996; 139: 240.
9. Saini NS, Kumar A, Mahajan SK, Sood AC. The use of ultrasonography, radiography and surgery in the successful recovery from diaphragmatic hernia in a cow. Can Vet J 2007; 48: 757-759.
10. Misk NA, Semieka MA. Radiographic appearance of reticular diaphragmatic herniation and traumatic pericarditis in buffaloes and cattle. Vet Radiol Ultrasound 2001; 42: 426-430.
11. Mohindroo J, Kumar M, Kumar A, Singh SS. Ultrasonographic diagnosis of reticular diaphragmatic hernias in buffaloes. Vet Rec 2007; 161: 757-758.
12. Kumar A, Saini NS. Reliability of ultrasonography at fifth intercostal space in the diagnosis of reticular diaphragmatic hernia. Vet Rec 2011; 169: 391.
13. Athar H, Mohindroo J, Singh K, Kumar A, Raghunath M. Comparison of radiography and ultrasonography for diagnosis of diaphragmatic hernia in buffaloes. Veterinary Medicine International 2010; 2010: 939870.
14. Kumar A, Saini NS. Diagnosis of a small-sized reticular diaphragmatic hernia in a buffalo. Vet Rec 2012; 171: 381-382.
15. Abdelaal A, Gouda S, Ismail A, Gomaa M. Reticular diaphragmatic hernia in Egyptian buffaloes: clinical, hemato-biochemical and ultrasonographic findings. Pak Vet J 2014; 34: 541-544.
16. Singh J, Krishnamurthy D, Chawla SK, Tayal R, Behl SM. Clinical evaluation of diversified ventral approaches to abdomen in buffaloes for diaphragmatic herniorrhaphy. Ind Vet J 2002; 79: 1149-1151.
17. Singh J, Prasad J, Kumar R, Kohli RN, Rathor SS. Treatment of diaphragmatic hernia in buffaloes. Aust Vet J 1977; 53: 473-475.
18. Prasad J, Singh J, Kumar RV, Kohli RN, Rathor SS. Management of diaphragmatic hernia in buffaloes. Indian Journal of Veterinary Surgery 1980; 1: 21-23.
19. Prasad B, Singh J, Khanna AK, Khianey NK, Kohli RN. Abomasal involvement in bovine diaphragmatic hernia and surgical management. Can Vet J 1979; 20: 26-27.
20. Busin V, Pozo JD, Sargison N. The diagnosis of diaphragmatic hernia in a 4-month-old Texel lamb. Livestock 2013; 18: 42-43.
21. Done SH, Drew RA. Aperture in the diaphragm with protrusion of abnormal liver tissue: a report of three cases of ox. Brit Vet J 1972; 128: 553-559.
22. Deshpande KS, Krishnamurthy D, Nigam JM, Sharma D. Patho-anatomy of herniation of the reticulum through the diaphragm in the bovine. Can Vet J 1981; 22: 234-236.
23. Venkataravanappa N, Krishnamurthy D. Biochemical constituents of diaphragm in cows and buffaloes. Ind J Anim Sci 1984; 54: 319-323.
24. Sangwan V, Mohindroo J, Kumar A, Mukhopadhyay CS, Saini NS. Doppler ultrasonography of common carotid artery and external jugular vein in healthy and reticulo-diaphragmatic hernia affected buffaloes. P Natl A Sci India B 2015; 85: 859-865.
25. Khalphallah AA, El-Sebaie AH, Raghib MF. Approach for diagnosis of complicated traumatic reticulo-peritonitis in cattle using ultrasonography. J Adv Vet Res 2015; 5: 157-164.
26. Braun U, Gotz M. Ultrasonography of the reticulum in cows. Am J Vet Res 1994; 55: 325-332.