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Ultrasound diagnosis of reticular diaphragmatic hernia in bovines[1]

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ABSTRACT.- Silva T.V., Cajueiro J.F.P., Silva N.A.A., Souza M.I., Costa N.A., Mendonça C.L., Afonso J.A.B. & Miranda Neto E.G. 2021. **Ultrasound diagnosis of reticular diaphragmatic hernia in bovines.** *Pesquisa Veterinária Brasileira 41:e06801, 2021.* Clínica de Bovinos de Garanhuns, Universidade Federal Rural de Pernambuco, Av. Bom Pastor s/n, Cx. Postal 152, Boa Vista, Garanhuns, PE 55292-272, Brazil. E-mail: ta_ty_vitor@hotmail.com

A reticular diaphragmatic hernia is a congenital or acquired alteration resulting from protrusion of the reticulum into the thoracic cavity. In ruminants, lesions to the diaphragmatic muscle, due to penetration of sharp metallic objects, is the most common cause of this disease. Therefore, given the low number of reports on this disease in the bovine species, the current study aims to describe the clinical, laboratory, and anatomopathological findings, with special emphasis on the ultrasound diagnosis of five cattle with reticular diaphragmatic hernia. The laboratory data were analyzed using mean and standard deviation, and clinical, ultrasound, and pathological findings were evaluated using descriptive statistics. Clinically the animals exhibited varying degrees of dehydration, abdominal distension, tympany, and alterations in ruminal motility, in addition to cardiorespiratory alterations such as murmur, dyspnea, and muffling of lung sounds. The laboratory examination showed neutrophilic leukocytosis and hyperfibrinogenemia. The ultrasonographic images demonstrated reticulum inside the thoracic cavity adjacent to the lung and heart, although no reticular motility was observed. The pathological lesions confirmed the findings of the ultrasound exams. Thus, the current study demonstrated that ultrasonography was efficient in diagnosing reticular diaphragmatic hernia in the bovine species.

INDEX TERMS: Ultrasound, hernia, bovines, cattle, diagnostic imaging, foreign body syndrome, reticulum.

RESUMO.- [**Diagnóstico ultrassonográfico da hérnia reticular diafragmática em bovinos.**] A hérnia reticular diafragmática é uma alteração congênita ou adquirida resultante da protrusão do retículo para o interior da cavidade torácica. Em ruminantes, lesões no músculo diafragmático devido a penetração de objetos metálico pontiagudos constitui a causa mais comum dessa enfermidade. Portanto, diante dos poucos relatos a cerca dessa enfermidade nos animais da espécie bovina, este estudo tem como objetivo descrever os achados clínicos, laboratoriais, anatomopatológicos e dar ênfase especial no diagnóstico ultrassonográfico de cinco bovinos acometidos com hérnia reticular diafragmática. Os dados laboratoriais foram analisados utilizando-se media e desvio padrão e os achados dos exames clínico, ultrassonográfico e anatomopatológicos foram avaliados através de estatística descritiva. Clinicamente os animais exibiam desidratação em variados graus, distensão abdominal, timpania e alterações na motilidade ruminal. Além de alterações cardiorrespiratórias como sopro, dispneia e abafamento dos sons pulmonares. O exame laboratorial revelou leucocitose por neutrofilia e hiperfibrinogenemia. As imagens ultrassonográficas revelaram retículo no interior da cavidade torácica adjacente ao pulmão e coração, porém nenhuma motilidade reticular foi observada. As lesões anatomopatológicas confirmaram os achados dos exames ultrassonográficos. Dessa maneira, este trabalho demonstrou que

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a ultrassonografia foi eficiente no diagnóstico da hérnia reticular diafragmática nos animais da espécie bovina.

TERMOS DE INDEXAÇÃO: Ultrassonografia, hérnia, bovinos, diagnóstico por imagem, síndrome do corpo estranho, retículo.

INTRODUCTION

Congenital or acquired failures in the diaphragmatic muscle result in diaphragmatic hernia, in which protrusion of the organs of the abdominal cavity into the thorax is observed. In ruminants, the reticulum is the most commonly herniated organ, resulting in a condition known as reticular diaphragmatic hernia, which has been reported in calves, goats, cattle, and buffaloes (Dirksen 2005, Mohindroo et al. 2007, Netto et al. 2008, Bellavance et al. 2010, Marques et al. 2014).

Generally, the most common causes of this disease are external trauma due to falls and blows, increased intra-abdominal pressure caused by bloating or advanced pregnancy, and weakening of the diaphragm by traumatic reticuloperitonitis lesions (Dirksen 2005, Netto et al. 2008, Marques et al. 2014).

Clinically, reticular diaphragmatic hernia is most commonly manifested through recurrent tympanism, regurgitation, inappetence, and scarce feces. These signs might be accompanied by dyspnea, cough, and predominantly abdominal breathing. Chest auscultation in the cardiac region may reveal sounds of reticular contractions and muffled heart sounds (Dirksen 2005, Constable et al. 2017).

The definitive diagnosis of this disease is obtained through exploratory laparotomy (Netto et al. 2008, Talekar et al. 2018) or through ultrasound visualization of the reticular wall and motility in the fourth right intercostal space of the thorax in cattle and buffaloes (Kumar & Saini 2011). In situations where imaging equipment is not available, thoracentesis has been described as an alternative diagnostic method (Misk 2015).

Although the indicated treatment for reticular diaphragmatic hernia is surgical correction, due to the severe impairment in the general condition observed in most affected animals, the best option in these conditions is slaughter or euthanasia of the animals (Constable et al. 2017). Researchers from India and Egypt have reported the use of ultrasound to diagnose reticular diaphragmatic hernia, mainly in buffaloes (Mohindroo et al. 2007, Abouelnasr et al. 2012, Abdelaal et al. 2014, Attia 2016).

However, there is little information about the use of this imaging method for the diagnosis of diaphragmatic reticular hernia in cattle. Therefore, the current paper proposes to present the clinical, laboratory, and anatomopathological findings with special emphasis on the ultrasound diagnosis of five cattle with reticular diaphragmatic hernia.

MATERIALS AND METHODS

The study was carried out at the "Clínica de Bovinos de Garanhuns" (CBG) campus of the "Universidade Federal Rural de Pernambuco" (UFRPE) through analysis of the clinical follow-up records, which also included the laboratory information, and ultrasound and necropsy reports of the cattle that were attended from 2016 to 2018. Five crossbreed female dairy cattle from dairy farms located in the Southern Agreste region of Pernambuco were studied.

All animals were clinically examined following the recommendations of Dirksen (1993). Blood samples were collected from four animals using a 21G needle through jugular venipuncture into vacutainer-type siliconized tubes containing EDTA anticoagulant (10%) to determine hematological variables (blood count, total plasma protein, and plasma fibrinogen), according to the methodology proposed by Jain (1993).

Reticulum ultrasound examinations were performed using Mode B apparatus (Z6 Vet, Mindray Bio-Medical Electronics Co. Ltd., Shenzhen, China) and a 5.0MHz convex transducer (3C5P), according to the methodology used by (Braun et al. 1993).

In animals euthanized with the permission of the owners, the technical recommendations of Luna & Teixeira (2007) were followed. Results pertaining to clinical, ultrasound, and anatomopathological findings were analyzed using descriptive statistics. Laboratory data were evaluated using measures of central tendency, mean, and standard deviation (Curi 1998).

This study was submitted and approved by the Ethics Committee on the Use of Animals (CEUA-UFRPE) under license number 105/2018, according to standards of the Brazilian College of Animal Experimentation (COBEA) and the National Institute of Health Guide for Care and Use of Laboratory Animals.

The affected cattle were five Holstein-Zebu crossbreed females, aged three to 14 years, one of which was reared in an extensive system and four semi-intensively. Only one was pregnant.

These animals presented a history of two to four weeks of clinical evolution, with complaints of reduced appetite, weight loss, decreased milk production, episodes of recurrent tympanism, and, in two cases, reflux of food content through the nostrils. Two of the affected cattle presented clinical signs between 15 and 30 days after calving.

RESULTS

Clinical observations

The absolute (n) and relative (%) frequencies of the main clinical findings of cattle with reticular diaphragmatic hernia are shown in Table 1.

Laboratory findings

The results of the laboratory examinations are shown in Table 2.

Ultrasound findings

The ultrasound findings that indicated the presence of reticular diaphragmatic hernia consisted of the visualization of the reticular wall in the third and fifth left intercostal space of the thorax and in the proximity of the reticulum with the organs of the thoracic cavity (Fig.1, 2 and 5). Reticular diaphragmatic hernia was not visualized through the ultrasound examination in only one of the five animals. These findings are described in Table 3.

Necropsy findings

Of the five cattle with reticular diaphragmatic hernia, only one was not authorized to be euthanized and in this case the diagnosis was obtained based on ultrasound examination only. Information related to the lesions found in the thoracoabdominal cavity of the necropsied animals, as well as the correlation with the ultrasonographic findings, are described in Table 4. In Figure 3, 5 and 6 it is also possible to observe the correspondence between ultrasound and anatomopathological findings.

DISCUSSION

The occurrence of reticular diaphragmatic hernia observed only in dairy cows could be attributed to the composition of the herd in the region, where there is a predominance of dairy cattle, in addition to the greater exposure of female dairy cattle to sharp metallic foreign bodies due to their higher productive longevity (Netto et al. 2008, Anteneh & Ramswamy 2015).

The occurrence of this disease in animals that have recently calved and in the final third of gestation was attributed to increased intra-abdominal pressure resulting in diaphragm rupture due to diaphragm fragility caused by trauma from penetration of foreign bodies from the reticulum (Dirksen 2005, Netto et al. 2008).

The clinical signs of reticular diaphragmatic hernia involve alterations in the digestive tract and cardiorespiratory system,

Table 1. Absolute and relative frequency of the main clinical signs of five cattle with reticular diaphragmatic hernia

Characteristics	Clinical findings	Number of animals	
		AF	RF (%)
Attitude	Standing	5	100
	Decubitus	-	-
Appetite	Present	2	40
	Absent	2	40
	Selective	1	20
Behavior	Calm	5	100
	Apathetic	-	-
Rectal temperature (oC)	Normal (37-39oC)	4	80
	Fever (>40oC)	1	20
Dehydration	Absent	-	-
	Mild (5-8%)	1	20
	Moderate (9-12%)	2	40
	Severe (>12%)	2	40
Heart rate	Normal (60-80)	4	80
	Low (<60)	-	-
	Increased (>80)	1	20
Cardiac alteration	Murmur	2	40
	Pre-stomach peristalsis	2	40
	No alteration	1	20
Respiratory frequency	Normal (24-36)	4	80
	Low (<24)	-	-
	Increased (>40)	1	20
Respiratory alteration	Dyspnea	2	40
	Muffled auscultation	2	40
	No alteration	1	20
Venous stasis	Positive	2	40
	Negative	3	60
Ruminal motility	Physiological	2	40
	Hypermotility	-	-
	Hypomotility	2	40
	Atonia	1	20
Ruminal tympany	Present	4	80
	Absent	1	20
Ruminal stratifications	Defined extracts	1	20
	Undefined extracts	4	80
Evidence of pain	Positive (in a test)	2	40
	Negative	3	60
Abdominal tension	Physiological	2	40
	Increased	3	60

AF = absolute frequency, RF = relative frequency.

Table 2. Hematological parameters, total plasma protein, and plasma fibrinogen of four cattle with reticular diaphragmatic hernia

Parameters	Animals				Mean±SD	Reference[a]
	1	2	3	4		
Hematocrit	21	31	34	35	30.25±6.40	24-46
Erythrocytes (106)	4.15	5.13	6.46	6.5	5.56±1.14	5-10
Hemoglobin (g/dL)	5.66	10.75	11.29	10.57	9.57±2.62	8-15
MCV[b] (fL)	50.60	60.40	52.63	53.84	55.63±4.19	40-60
MCHC[c] (%)	26.9	34.67	33.2	31.34	31.53±3.37	30-36
Total leukocytes (µL)	15350	14800	11050	10000	12800±2671	4000-1200
Lymphocytes (µL)	3070	5328	8067	6800	5816±2146	2500-7500
Segmented neutrophils (µL)	11820	9176	2320	3100	6604±4675	600-4000
Band neutrophil (µL)	0	148	0	0	37±74	0-120
Eosinophils (µL)	0	0	663	0	166±332	0-2400
Monocytes (µL)	460	148	0	100	177±198	25-840
Basophils (µL)	0	0	0	0	0±0	0-200
TPP[d] (g/dL)	8.8	6.8	7.8	7.4	7.7±0.84	7-8.5
PF[e] (g/dL)	1800	400	800	600	900±622	300-700

[a] Jain (1993), [b] MCV = mean corpuscular volume, [c] MCHC = mean corpuscular hemoglobin concentration, [d] TPP = total plasma protein, [e] PF = plasma fibrinogen.

Table 3. Ultrasound findings of the abdominal and thoracic cavity of five cattle with reticular diaphragmatic hernia

Parameters	Number of animals		
	Ultrasound finding	AF	RF (%)
	Abdominal cavity		
Reticular contour	Smooth	-	
	Irregular	5	100
Reticular positioning	Supported by the diaphragm	3	60
	Dorsally displaced	2	40
Number of contractions in 3 minutes	3-4 (normal)	2	40
	1-2 (reduced)	-	
	5-9 (hypermotile)	-	
	0 (atonic)	-	
	No information	3	60
Contraction pattern	Biphasic	2	40
	Triphasic	-	
	No information	3	60
	Thoracic cavity		
Reticular contour	Smooth	-	
	Irregular	4	80
Reticular positioning	Supported by the heart	1	20
	Caudal to the lung	3	60
Number of contractions in 3 minutes	3-4 (normal)	-	
	1-2 (reduced)	-	
	5-9 (hypermotile)	-	
	0 (atonic)	4	80
	No information	-	
Contraction pattern	Biphasic	-	
	Triphasic	-	
	No information	-	
Reticulum not visualized in the chest		1	20

AF = absolute frequency, RF = relative frequency.

Table 4. Correspondence between ultrasound findings and anatomopathological lesions in the reticulum of cattle with reticular diaphragmatic hernia

Ultrasound findings	AF	Anatomopathological findings	AF	Correspondence
Motility absent	5	Adhesions	4	80%
Reticulum caudal to the lung	3	Reticulum adhered to the lung	3	100%

AF = absolute frequency.

as found in the animals of the current study. Which shown tympanism, reflux of food content, and inappetence can be attributed to entrapment of the reticulum inside the chest (Netto et al. 2008, Athar et al. 2010, Kumar & Saini 2011).

Cardiac murmur, dyspnea, and muffling in the auscultation of the pulmonary fields, as detected in some of the cattle, occur because the herniated reticulum causes a shift of the heart and changes in intrathoracic pressure, resulting in the cardiorespiratory alterations (Dirksen 2005, Abdelaal et al. 2014, Constable et al. 2017).

The laboratory alterations observed were characterized by leukocytosis accompanied by hyperfibrinogenemia and only suggest the presence of an inflammatory process, having little value for the exact diagnosis of the disease (Weiser 2015, Constable et al. 2017). These alterations is the most frequent hematological finding in cases of reticular diaphragmatic hernia, which was also reported in Egyptian buffaloes (Abdelaal et al. 2014, Attia 2016).

The ultrasonographic detection indicated the presence of reticular diaphragmatic hernia in the animals of the current study was characterized by the presence of an image in format of a half moon and with smooth contour (corresponding to the ultrasonographic description of the reticulum) and absence of a reticulum motility observed in the thorax. This observation was similar to those verified in another study with buffaloes, in which it was observed the reticular wall and lack of its motility in the fifth left intercostal space of the thorax (Attia 2016). However, a previous study has shown that the fourth intercostal space of the right antimere is the most reliable site for demonstrating reticular diaphragmatic hernia (Kumar & Saini 2011).

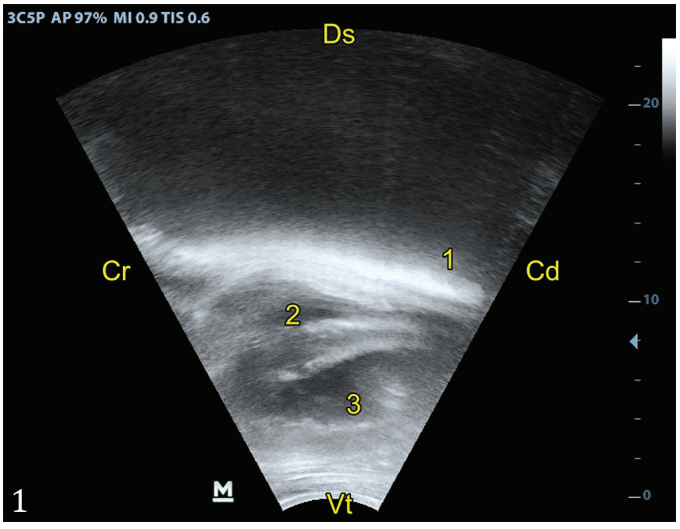

Fig.1. Ultrasound image of the third left intercostal space in cattle with reticular diaphragmatic hernia: visualization of the reticular wall resting on the heart and compressing it. Reticular wall (1), right ventricle (2), left ventricle (3), cranial (Cr), caudal (Cd), ventral (Vt), dorsal (Ds).

The absence of a reticulum motility pattern within the thoracic cavity could be attributed to reticulum entrapment or the presence of strong peri-reticular adhesions (Athar et al. 2010, Kumar et al. 2017). However, although some authors consider that reticular motility within the chest is a decisive finding for the correct diagnosis of reticular diaphragmatic hernia (Mohindroo et al. 2007, Athar et al. 2010, Kumar & Saini 2011), false positive diagnoses were reported in animals that presented reticular motility at the level of the fifth intercostal space due to cranial displacement of the reticulum caused by abdominal distension (Athar et al. 2010).

On the other hand, a false negative diagnosis may occur when only a small portion of the reticulum is herniated, thus, ultrasound visualization of the viscera inside the chest is not possible and in the current study this prevented the ultrasound diagnosis in one of the cattle. In addition, when the reticulum is located far from the chest wall, out of the transducer range, and covered by the lungs, a diagnosis of diaphragmatic reticular hernia is not possible (Kumar & Saini 2011, Constable et al. 2017). Although no reticular motility within the chest was observed, visualization of the reticulum adjacent to the heart and lung was a determining finding for the diagnosis of reticular diaphragmatic hernia. These findings were similar to those observed in other studies (Abdelaal et al. 2014, Kumar et al. 2017).

There are no studies in the literature comparing the ultrasound diagnosis of diaphragmatic reticular hernia with necropsy images in cattle, thus, this is the first study to confirm the ultrasound images of cattle with reticular diaphragmatic hernia through the observation of anatomopathological lesions. However, Kumar & Saini (2011), Kumar et al. (2017) confirmed the ultrasound diagnosis of RDH through exploratory laparotomy and the observations of these authors were similar to those

Fig.2-4. (**2**) Ultrasound image of the 5th left intercostal space in cattle with reticular diaphragmatic hernia: visualization of the reticular wall caudal to the lung. (**3,4**) Anatomopathological lesions corresponding to previous ultrasound image. Chest wall (1), lung (reverberation) (2), reticular wall (3), reticular wall contour within the chest (arrow), cranial (Cr), caudal (Cd), ventral (Vt), dorsal (Ds).

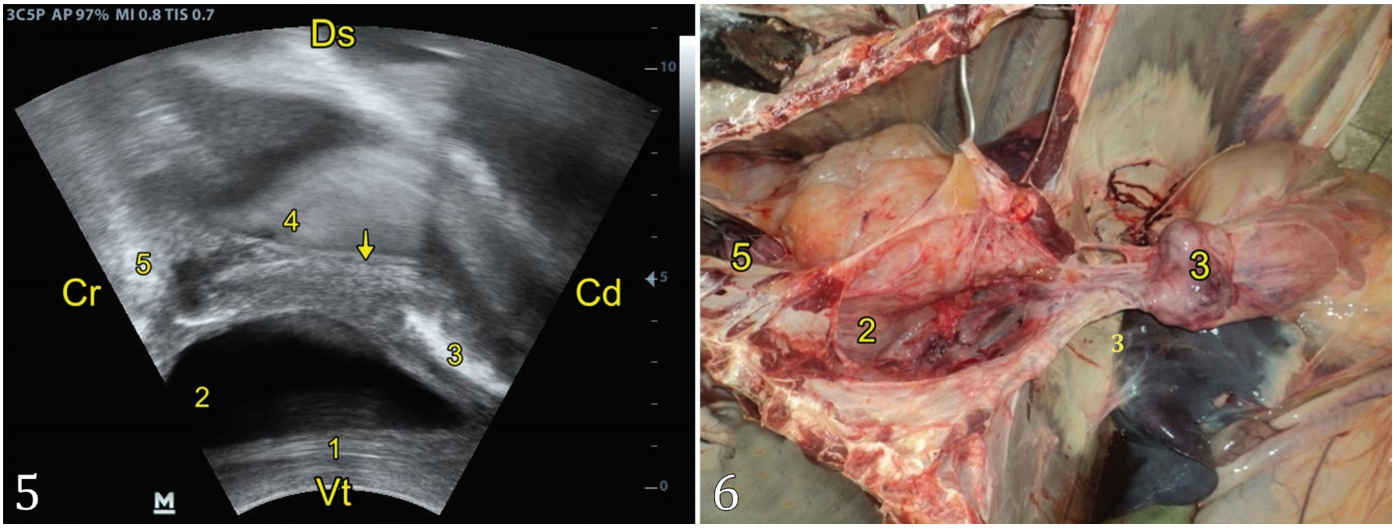

Fig.5-6. (**5**) Ultrasound image of the 5th left intercostal space in cattle with reticular diaphragmatic hernia: visualization of the reticular wall caudal to the lung. (**6**) Anatomopathological lesions corresponding to previous ultrasound image: accumulation of inflammatory fluid and reticular wall. Chest wall (1), accumulation of inflammatory fluid (2), reticular wall (3), left ventricular wall (4), lung (5), left atrium (6), ventricular wall with adhered inflammatory material (fibrin) (arrow), cranial (Cr), caudal (Cd), ventral (Vt), dorsal (Ds).

observed in this study. Both in the exploratory laparotomy performed by Kumar & Saini (2011), Kumar et al. (2017) and in the necropsy of the cattle in this study, a herniary ring in the diaphragm and herniated reticulum into the chest cavity were observed. Thus, these findings corroborate those of the ultrasound examination.

CONCLUSION

Visualization of the reticular wall in the fifth and third intercostal spaces of the left antimere as well as the finding of the proximity of the reticulum to the organs of the thoracic cavity were decisive findings for the diagnosis of reticular diaphragmatic hernia in cattle, since these findings were confirmed in the necropsy of the animals. Therefore, visualization of motility of the herniated portion of the reticulum was not necessary for the diagnosis of this disease, since adhesions on thoracic organs may prevent this function.

Conflict of interest statement.- The authors declare that there are no conflicts of interest.

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