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Ultrasonography as a Differential Diagnostic Tool of Bovine Respiratory Tract Disorders with Reference to Serum Haptoglobin and Lipid Profiles Changes

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Abstract

Respiratory diseases of cattle represented the most important health and economic problems of cattle rearing. It was possible to diagnose ultrasonographically bronchopneumonia, consolidation, pulmonary emphysema, pleural effusion and pleuritis. The study aimed to correlate between the changes in clinical findings and laboratory assays mainly haematological pictures and serum acute phase proteins (APPs) i.e. haptoglobin, and the characteristic ultrasonographic findings in bovine respiratory diseases and their importance in differentiation between upper respiratory diseases and lower respiratory diseases in cattle. A total number of 84 cattle were included in the study and divided into 3 groups: healthy control group (n=15), upper respiratory diseased group [U_RG] (n=29) and lower respiratory diseased group [L_RG] (n=40). The animals were admitted to the Veterinary Teaching Hospital at Assiut University-Egypt with a history of anorexia, respiratory distress, nasal discharge, cough and/or abnormal lung sounds. These animals were undergoing clinical and ultrasonographic examinations as well as laboratory analyses. Regarding to the ultrasonographic findings, the diseased cases were classified into U_RG and L_RG. Ultrasonography differentiated many of the affections such as bronchopneumonia (n=16), Lung consolidation (n=12), pulmonary emphysema (n=8), and pleuritis and pleural effusion (n=4). Neutrophilic leukocytosis was reported in U_RG and L_RG. The biochemical assays revealed significant elevation in serum levels of haptoglobin, fibrinogen, total cholesterol, triglyceride, high density lipoprotein cholesterol and very low-density lipoprotein in U_RG and LRG. Serum albumins were remarkably ($P<0.05$) decreased in U_RG. The study concluded that thoracic ultrasonography considered a diagnostic tool in cows with respiratory diseases because it determined the location and extent of the lung lesions as well as the severity of the affection. APPs and lipid profile used as biomarkers for the diagnosis of bovine respiratory diseases.

KEYWORDS
cattle, haptoglobin, bronchopneumonia, pulmonary emphysema, upper and lower respiratory diseases, thoracic ultrasonography.

INTRODUCTION

Bovine respiratory disease (BRD) defined as a complex, multifactorial syndrome, in which the interaction between infectious etiological agents (bacteria and virus), external stressors, and the animal's immune system influences the development of the disease (Panciera and Confer, 2010). It was the most prevalent disease of recently weaned feedlot calves (Murray *et al.*, 2017; Hay *et al.*, 2017; Wilson *et al.*, 2017) and caused high economic losses due to reduced animal performance, higher mortality rates, and elevated therapy costs (Cernicchiaro *et al.*, 2013; Blakebrough-Hall *et al.*, 2020) as well as negatively impacting animal welfare (Wolfger *et al.*, 2015).

Numerous diagnostic methods were used to evaluate BRD including auscultation, percussion, laboratory analysis, radiography, ultrasonography, and more invasive procedures such as aspirations and biopsies (Radostits *et al.*, 2007; Wilson *et al.*, 2017).

The biggest challenge in clinical diagnosis of BRD was the absence of a gold standard test. The routine diagnostic methods of BRD included thorough clinical examination and thoracic auscultation but auscultation was difficult in calves and abnormal lungs sounds might not be audible (Joshi *et al.*, 2016).

Wittum *et al.* (1996) and Young *et al.* (1996) reported that bovine acute phase proteins (APPs) mainly haptoglobin (Hp) had limited capacity as a diagnostic clinical tool for BRD in feedlot cattle. Later, Hp was considered useful for identifying beef calves with BRD, in need for treatment and for monitoring treatment efficacy (Carter *et al.*, 2002; Humblet *et al.*, 2004), whereas other APPs like serum amyloid A (apoSAA) and α1-acid glycoprotein (AGP) was not found to be a useful marker of BRD in feedlot calves and dairy heifers (Carter *et al.*, 2002; Berry *et al.*, 2004; Khalphallah *et al.*, 2016a,b).

Changes in lipid levels had been reported in a variety of infectious diseases. Lipoproteins seemed to have a role in innate immunity. Furthermore, the host response during infections is mediated by proinflammatory cytokines, which were capable of influencing lipid metabolism in the liver (Fraunberger *et al.*, 1999; Van Leeuwen *et al.*, 2003). Therefore, the circulating lipoproteins

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seemed to play a crucial role in the pathophysiology of infectious diseases.

The severity of disease could not always be determined using means of physical examination alone. Although physiological lung tissue cannot be examined, as ultrasound waves were unable to penetrate gas-filled structures, sonography was suitable for describing several pathological conditions within the thoracic cavity. Based on the sonographic appearance of the pulmonary surface and the fluid in the pleural cavity, valuable prognostic information might be obtained, and the healing process better followed (Braun, 1997; Reef, 1998; Scott, 1998).

In cattle, ultrasonography of the upper respiratory tract was less frequent (Braun *et al*., 1994), due to the use of endoscopy; however, ultrasonography might be useful in the assessment of masses such as abscesses of the soft tissue surrounding the larynx and trachea.

Ultrasonography of the lungs and pleura was reported in several research projects and publications in cattle (Flöck, 2004; Jung and Bostedt, 2004; Ollivett and Buczinski, 2016; Hussein *et al*., 2018; Abdallah *et al*., 2019; Cramer and Ollivett, 2019; Braun *et al*., 2020). It was particularly useful for diagnosis and characterization of pleural effusion, especially small amounts, the detection of pneumothorax, superficial pulmonary lesions or consolidation and pulmonary atelectasia. In some cases, an ultrasonographic examination added further precision to a radiographic examination (Reef *et al*., 1991). This was particularly true regarding the cranioventral part of the thorax, because radiographs of this region were more difficult to analyze because of overlap of the soft tissue, bone, and the cardiac silhouette.

Thoracic ultrasonography was a useful tool in combination with clinical respiratory score (CRS) and other conventional methods to detect lung lesions. They could provide a more accurate and early diagnosis of BRD, which was fundamental to successful treatment, animal welfare, and growth performance (Cuevas-Gómez *et al*., 2020). Thoracic ultrasonography was used at the herd level to identify specific herds at risk for developing BRD and to follow the prevalence and severity of BRD over time, as well as any responses to management changes such as changes in treatment protocols, vaccination or ventilation (Ollivett and Buczinski, 2016).

Accordingly, the study aimed to correlate between the changes in clinical findings and laboratory assays mainly haematological pictures and serum haptoglobin, and the characteristic ultrasonographic findings in bovine respiratory diseases and their importance in differentiation between upper and lower respiratory diseases in cattle.

MATERIALS AND METHODS

Animals

A total number of 84 cattle, their ages ranged between 3.5 months-3 years. were admitted to the Veterinary Teaching Hospital at Assiut University-Egypt with a history of anorexia, respiratory distress, nasal discharge, cough and/or abnormal lung sounds, and were included in the study. History of paraffin oil and ruminal tonics drenching was reported in some animals and might lead to drenching pneumonia.

Ethical approval

All experimental protocols were approved by Institutional Animal Care and Use Committee guidelines of Assiut University which basically was in accordance with the Guide for Laboratory Animals Care and Use of the National Institutes of Health in the USA (NIH publication No. 86-23, revised 1996).

Samples

Whole blood sample collected on EDTA and stored at 4°C until analysis. Blood serum samples collected on plain vacutainer tubes and stored at -20 °C until analysis according to Coles (1986).

Clinical examination

Clinical examination of the animals was conducted using clinical chart according to Cockcroft (2015).

Complete blood picture indices and plasma fibrinogen estimation

Various hematological indices including red blood corpuscles (RBCs), total leucocytic count (TLC), hemoglobin (Hb) and packed cell volume (PCV)were measured by a fully automated blood cell counter machine (Medonic CA620 Vet hematology analyzer, Sweden). Differential leukocytic count (DLC) was determined using four field meander method (Coles, 1986). Plasma fibrinogen level was determined semi quantitatively by using the routine heat precipitation technique (Millar *et al*., 1971).

Biochemical assays

Hp was determined using ELISA haptoglobin test kit (Second generation) (Tridelta Development Ltd. Biorepair GmbH, Germany).

Spectro UV-Vis RS spectrophotometer (Labomed, Inc. USA) was used to determine serum concentrations of total protein, albumin, cholesterol, triglycerides (TG), high density lipoprotein (HDL), alanine aminotransferase (ALT) and aspartate aminotransferase (AST). All kits and reagents were obtained from Spectrum Reagents (Spectrum Diagnostics, Egyptian Company for Biotechnology, Egypt). Serum globulins were estimated by subtraction of albumin from total protein and their values used to calculate albumin/globulin ratio (A/G ratio).

Very low density lipoproteins (VLDL) and low density lipoproteins (LDL) were calculated with an equation: VLDL = triglyceride/5 while LDL = total cholesterol - (HDL cholesterol + triglyceride / 5) (Basoglu *et al*., 2002).

Ultrasonographic examination

The thoracic lung ultrasound technique was performed as previously described (Braun, 1997; Flöck, 2004; Babkine and Blond, 2009; Adams and Buczinski, 2016; Buczinski *et al*., 2014; Ollivett and Buczinski 2016; Braun *et al*., 2020). Ultrasonographic examination of thoracic region from the right and left sides was conducted in diseased and healthy animals using a 4–6 MHz micro convex ultrasound for calves, where the frequency was changed according to the examination's requirement, and a 3.5-5 MHz convex transducer connected with ultrasound apparatus with multifrequency for older one (MyLab™One VET, Esaote, Italy).

Statistical analysis

Data were analyzed using SPSS statistical software program for windows version 10.0.1 (SPSS Inc., Chicago, IL., USA). The obtained data were described as mean ± standard deviation (SD). The independent-sample t-test was used whereas the significance of differences between the means of control group and either of U_RG or L_RG was evaluated. The data obtained were also analyzed by independent-sample. The significance of differences between the means of U_RG and those of L_RG, was evaluated by Dunnett's test at $P<0.05$.

RESULTS

Animals were divided into 3 groups: healthy control group (n=15), U_RG (n=29) and L_RG [thoracic group] (n=40) according to the clinical finding's characteristic to the upper respiratory diseases and to those characteristic to pulmonary involvements. The control group had native breed (n=7) and Friesian (n= 8). U_RG (n=29) included native breed (n=10) and Friesian (n=19), hence, L_RG (n=40) included native breed (n=17) and Friesian (n=23). The control group included healthy non-pregnant cows. U_RG (n=29) included males (n=13) and females (n=16), hence, L_RG (n=40) included males (n=14) and females (n=26).

History and clinical findings

U_RG included affections of the nasal cavity, nasopharynx, larynx and trachea that were expressed as one syndrome including all these organs. The affections extended to the whole upper respiratory tract and did not restrict to one organ. L_RG included affections of the thorax including lung and pleura. The clinical findings in both U_RG and L_RG were characteristic for respiratory disorders as the study reported feverage conditions, polypnoea, anorexia, cough, abnormal nasal discharge, respiratory noise (snorting or whistling sound), dyspnea and congested nasal mucous membranes and enlarged submaxillary lymph nodes in the two diseased groups. Tachycardia, harried respiratory movement, accelerated respiratory rate and reduced ruminal motility were more pronounced with L_RG meanwhile enlarged larynx and swollen submaxillary lymph nodes were mostly common with U_RG. The abnormal tracheal sounds were heard only with U_RG, hence, the abnormal lung sounds were heard only with L_RG. Furthermore, foul-smelling nasal discharges, pleurodynia and expiratory grunting were notable only with L_RG particularly pleurisy and aspiration pneumonia. The viscosity and quality of nasal discharges as well as productivity and frequency of cough differed in U_RG than in L_RG. Generally, the severity of clinical findings was more observable with L_RG. These clinical findings were clearly described in Tables 1, 2 and 3.

Complete blood picture indices and plasma fibrinogen concentration

The whole blood pictures showed no significant changes either between the control group and each of U_RG and L_RG, or between the two diseased groups except for TLC and DLC. They were within the reference ranges. Both of U_RG and L_RG showed significant ($p<0.05$) increase TLC and neutrophils (neutrophilic leukocytosis) when their values compared with those in control group. Plasma fibrinogen concentrations were remarkably ($p<0.05$) elevated at the two diseased groups when comapring with their values in control cattle. The significant changes in TLC, neutrophils and plasma fibrinogen levels were not observed between U_RG and L_RG, hence, their levels were higher than the reference ranges (Table 4).

Biochemical assays

Serum Hp concentrations were significantly ($p<0.05$) increased in U_RG and L_RG comparing to their values in control animals. These remarkable changes were not described between U_RG and L_RG. Serum levels of Hp in cattle with respiratory affections were higher than their reference ranges (Table 4).
The blood concentrations of total proteins and globulins as well

Table 1. The common clinical findings in the control and diseased groups of cattle.

Parameters	Control	U_RG	L_RG
	n=15	n=29	n=40
Fever (≥39.6 Ċ)	0 (0)*	29 (100)	40 (100)
Polypnoea (≥30 /m)	0 (0)	29 (100)	40 (100)
Tachycardia (≥90 b/m)	0 (0)	0 (0)	32 (80)
Normal appetite	100 (100)	0 (0)	0 (0)
Inspiratory dyspnoea	0 (0)	22 (75.86)	36 (90)
Oral breathing-dilated nostrils	0 (0)	18 (62.07)	36 (90)
Cough	0 (0)	29 (100)	40 (100)
Nasal discharge	0 (0)	29 (100)	40 (100)
foul-smelling nasal discharge	0 (0)	0 (0)	30 (75)
Congested Nasal mms	0 (0)	29 (100)	40 (100)
Abnormal tracheal sound	0 (0)	20 (68.97)	0 (0)
Abnormal lungs sound	0 (0)	0 (0)	40 (100)
Abnormal respiratory noise	0 (0)	18 (62.07)	30 (75)
Expiratory grunting	0 (0)	0 (0)	25 (62.5)
Pleurodynia	0 (0)	0 (0)	10 (25)
Swelling of submaxillary LNs	0 (0)	15 (51.72)	3 (7.5)
Swelling of larynx	0 (0)	17 (58.62)	2 (5)
Ruminal hypomotility	0 (0)	13 (44.83)	34 (85)
Congested conjunctiva	0 (0)	2 (6.9)	3 (7.5)
Dehydration	0 (0)	1 (3.45)	3 (7.5)

*Number of cows (%). URG: upper respiratory diseased group. LRG: lower respiratory diseased group. MMs: mucous membranes. LNs: lymph nodes.

Table 2. The common clinical findings in the control and diseased groups of cattle

Parameters	Control n=15	U_RG n=29	L_RG n=40
Cough	Absent	Dry, paroxysmal and painful, mainly. Moist and intermittent, sometimes	Moist and intermittent, mainly. Dry, paroxysmal and painful, sometimes.
Nasal discharge	Absent	Serous to seromucoid or mucoid. Scanty and watery. Unilateral mainly.	Mucopurulent or purulent Profuse, frothy and stick. Bilateral mainly.
Tracheal sound	Normal CH sound	Harsh and loud CH sound	Normal CH sound
Lung sound	Ausc.: VS.	Ausc.: VS.	Ausc.: Exaggerated VS, râles (moist, dry or cripitant), pleuritic frictional rub or absence of lung sounds.
	Perc.: resonant	Perc.: resonant	Perc.: hyper-resonant or dull
Ruminal motility	Normal	Reduced or normal	Reduced or ceased

URG: upper respiratory diseased group. LRG: lower respiratory diseased group. MMs: mucous membranes. Ausc.: auscultation. Perc.: percussion. VS: vesicular sound.

Table 3. Mean values of temperature, pulse, respiration and rumen movement in the control and diseased groups of cattle

Parameters	Control n=15	U_RG n=29	L_RG n=40
Temperature (°C)	38.49±0.37	39.7±0.8	39.8±1.1
Pulse (Beat/min)	72.80±6.41	82.3±6.5	87.7±4.5*
Respiration (/min)	20.14±2.39	50.5±8.6*	58.6±5.5*
Rumen (cycle/2 mins)	2.80±0.44	1.5±0.22*	1.2±0.68*

URG: upper respiratory diseased group. LRG: lower respiratory diseased group. *Significant when the values at URG or at LRG compared with those at control group (*p<0.05).

Table 4. Mean values ± standard deviation of blood picture and serum biochemical indices in the control and diseased groups of cattle

Parameters	Control n=15	U_RG n=29	L_RG n=40
RBCs ($_x10^{12}$/L)	7.56±0.81	7.08±1.61	8.08±2.56
PCV (L/L)	0.29±0.03	0.26±0.07	0.31±0.08
Hb (g/L)	111±9.9	105.4±20.5	103.5±25.4
TWBCs ($_x10^9$/L)	8.55±1.29	11.75±1.65*	15.31±2.96*
Neutrophils ($_x10^9$/L)	2.46±0.66	5.60±1.47*	7.67±1.72*
Lymphocytes ($_x10^9$/L)	5.32±0.97	6.60±1.84	6.23±2.05
Monocytes ($_x10^9$/L)	0.20±0.04	0.63±0.07	0.70±0.03
Eosinophils ($_x10^9$/L)	0.25±0.09	0.15±0.08	0.26±0.05
Band cells ($_x10^9$/L)	0.32±0.07	0.24±0.07	0.45±0.04
Plasma fibrinogen (g/L)	5.80±0.52	9.22 ± 2.94*	9.76±2.92*
Haptoglobin (g/l)	0.34±0.07	0.50±0.22*	0.48 ± 0.19*
Total proteins (g/L)	53.6±4.2	64.1±12.5*	66.7±11.9*
Albumin (g/L)	32.7±4.8	29.6±5.4	30.3±6.8
Globulin (g/L)	20.9±8.2	32.5±2.4*	36.4±7.7*
A/G ratio	1.88±0.59	0.91±0.04*	0.83±0.06*
Cholesterol (mmol/L)	2.24±0.14	3.27±0.69*	3.62±0.84*
Triglycerides (mmol/L)	0.08±0.02	0.3±0.05*	0.27±0.06*
HDL (mg/ dl)	75.03±6.65	106.06±21.31*	107.60±22.71*
LDL (mg/ dl)	51.11±5.77	24.02±7.43*	25.25±7.04*
VLDL (mg/ dl)	1.59±0.46	5.32±1.82*	4.78±1.88*
ALT (U/L)	7.36±0.91	10.07±3.18*	9.57±3.13*
AST (U/L)	34.96±3.77	21.79±5.05*	20.87±6.78*

URG: upper respiratory diseased group. LRG: lower respiratory diseased group. RBCs: total red blood corpuscles. PCV: packed cell volume. Hb: haemoglobin concentration. TWBCs: total white blood cells count A/G: albumin/globulin ratio. HDL: high density lipoprotein. LDL: low density lipoproteins. VLDL: Very low density lipoproteins. ALT: Alanine aminotransferase. AST: Aspartate aminotransferase. *Significant when the values at URG or at LRG compared with those at control group (*p<0.05).

Table 5. Categorization and percentage of respiratory tract affections in disease cattle based on ultrasonographic findings

Diseased group (n=69) (100%)								
URG	LRG (n=40) (57.97%)							
(n=29) (42.01%)	Bronchopneumonia		Lung consolidation		Emphysema		Pleurisy and pleural effusion	
	Number	(%)	Number	(%)	Number	(%)	Number	(%)
	16	23.19	12	17.39	8	11.59	4	5.8

URG: upper respiratory diseased group. LRG: lower respiratory diseased group. %: percentage of diseased cattle.

as A/G ratio (Table 4) were greatly changed in diseased cattle where significant elevations ($p<0.05$) in serum total proteins and globulins were stated in U_RG and L_RG meanwhile A/G was significantly ($p<0.05$) reduced in both diseased groups comparing to their values in control cattle. These remarkable changes were not detected between U_RG and L_RG. Their serum concentrations in diseased cattle were within their reference ranges. Serum albumins levels were not significantly changed either in the two diseased group when compared with the control one or between U_RG and L_RG when their values were compared with each other.
The lipid profiles were clearly changed in cattle with respiratory affection either for U_RG or L_RG as remarkable ($p<0.05$) elevations in serum concentrations of cholesterol, triglycerides, HDL, VLDL and ALT as well as remarkable ($p<0.05$) reductions in serum levels of LDL and AST were reported in both U_RG or L_RG when their values compared with those in control group. No significant changes for blood lipid profiles were observed between U_RG and L_RG. The serum concentrations of estimated lipid profiles in all investigated animals either healthy or diseased, were within the reference ranges (Table 4).

Ultrasonographic findings

In control group, normal lung tissue could not be imaged due to its air content but reverberation artifacts in the form of echogenic bands running parallel to the lung surface were visible. The visceral pleura (pulmonary) and the lung surface form a hyperechogenic line known as the pleural line. The parietal pleura (costal) can only be differentiated from the visceral pleura during a real-time examination, during which the gliding sign, which was the sliding movement of the lung during respiration was observed and appeared as a smooth hyperechoic line between the lungs surface and the thoracic wall (Fig. 1).

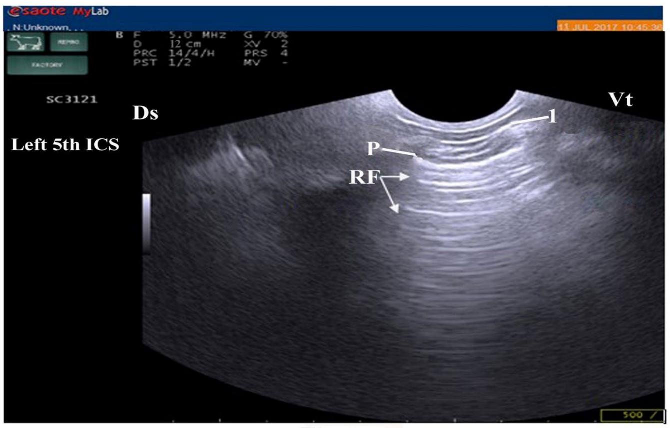

Fig. 1

Fig. 1. Ultrasonogram of the surface of a normal lung (caudal aspect of the cranial lobe) in a 2 years-old non pregnant cow imaged from the middle part of the thorax in the left 4th ICS by using 5 MHz convex array transducer. It showed echogenic line represented visceral and parietal pleura (P) as well as echogenic lines running parallel to the pulmonary surface which were referred as reverberation artifacts (RA). 1, thoracic wall or paries thoracis; Ds, Dorsal; Vt, Ventral.

Ultrasonographic findings in cattle with respiratory diseases were diagnostic and useful in differentiation between the upper and lower respiratory tract affections. They also were helpful in categorization different pulmonary affections. The current study classified the upper respiratory diseases [U_RG] (42.01%) as well as the bronchial and pulmonary affections [L_RG] (57.97%) based on the ultrasonographic findings through estimating the percentages and prevalence rate of each affection (Table 5). Out of forty cattle [L_RG], the pulmonary affections included bronchopneumonia (n=16), lung consolidation (n=12), pulmonary emphysema (n=8) and pleura effusions and pleurisy (n=4).

Regarding to U_RG, the ultrasonographic findings revealed healthy normal sonographic appearance of the lung, pleura and bronchi (Fig. 2). No characteristic abnormal findings were visualized.

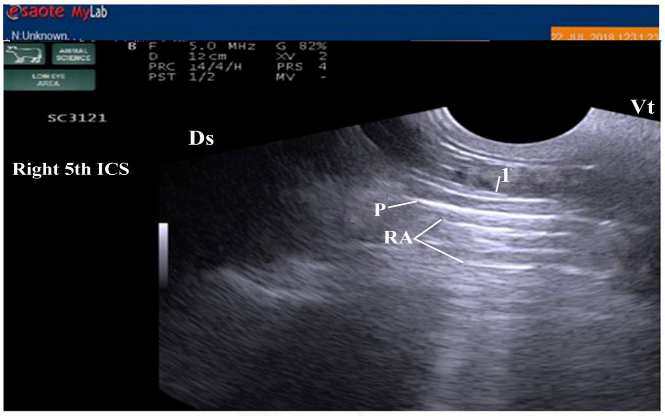

Fig. 2

Fig. 2. Ultrasonogram in a 1.5 years-old cow-bull with URG affections imaged from the middle part of the thorax in the right 5th ICS by using 5 MHz convex array transducer. It showed normal lung (middle lobe). An echogenic line (white arrow) represented visceral and parietal pleura as well as echogenic lines (P) running parallel to the pulmonary surface which were referred as reverberation artifacts (RA), were visualized. 1, thoracic wall or paries thoracis; Ds, Dorsal; Vt, Ventral; URG, upper respiratory diseased group.

L_RG showed several characteristic ultrasonographic findings that described several thoracic affections. In cattle with bronchopneumonia, the ultrasonographic images were variables as complete (extensive) (Figs. 3a, b, d, 4) lung consolidations in case of severe persistent chronic bronchopneumonia or partial (localized) (Fig. 3c) lung consolidations in case of less severe chronic bronchopneumonia were observed. Extensive pulmonary consolidation in which the whole cranioventral pulmonary lobe (cranioventral portions of the main lung lobes) was affected, appeared as rounded or wedge-shaped hypoechoic, and often heterogeneous zones with comet-tail artifacts (COMT) were visualized on the surface of the lung i.e. the cranioventral lobe of the lung. These extensive hypoechoic zones resembling liver parenchyma without reverberation artifacts were seen and were well demarcated from healthy tissue. The anechoic areas represented necrotic or fluid-filled areas. Hepatisation of lung parenchyma occurred with severe consolidation, resulting in an ultrasonographic appearance similar to that of a liver (Figs. 3a, b, d, 4). Lung consolidations in some diseased cases with bronchopneumonia and/or aspiration pneumonia imaged as echogenic regions with COMT (Fig. 5a). These Extensive changes (consolidations) are particularly evident in the cranioventral lung fields as well as in individual areas of the dorsal lung, in otherwise physiologically normal lung tissue.

In cattle with bronchopneumonia, the extensive hypoechoic zones resembling liver parenchyma without reverberation artifacts were seen and were well demarcated from healthy tissue. Within the hypoechoic zones were disseminated hyperechoic and anechoic dot-shaped as well as some branched line-shaped structures (Figs. 3a, b, 4) and also tubular structures with walls of varying echogenicity and ramification towards the lung periphery with hypoechoic to hyperechoic content (Fig. 3d).

Pulmonary consolidation could be localized, such as in aspiration pneumonia. When aspiration pneumonia was suspected upon physical examination (history: foul-smelling breath, dyspnoea, outstretched posture of the head and neck), mild abnor-

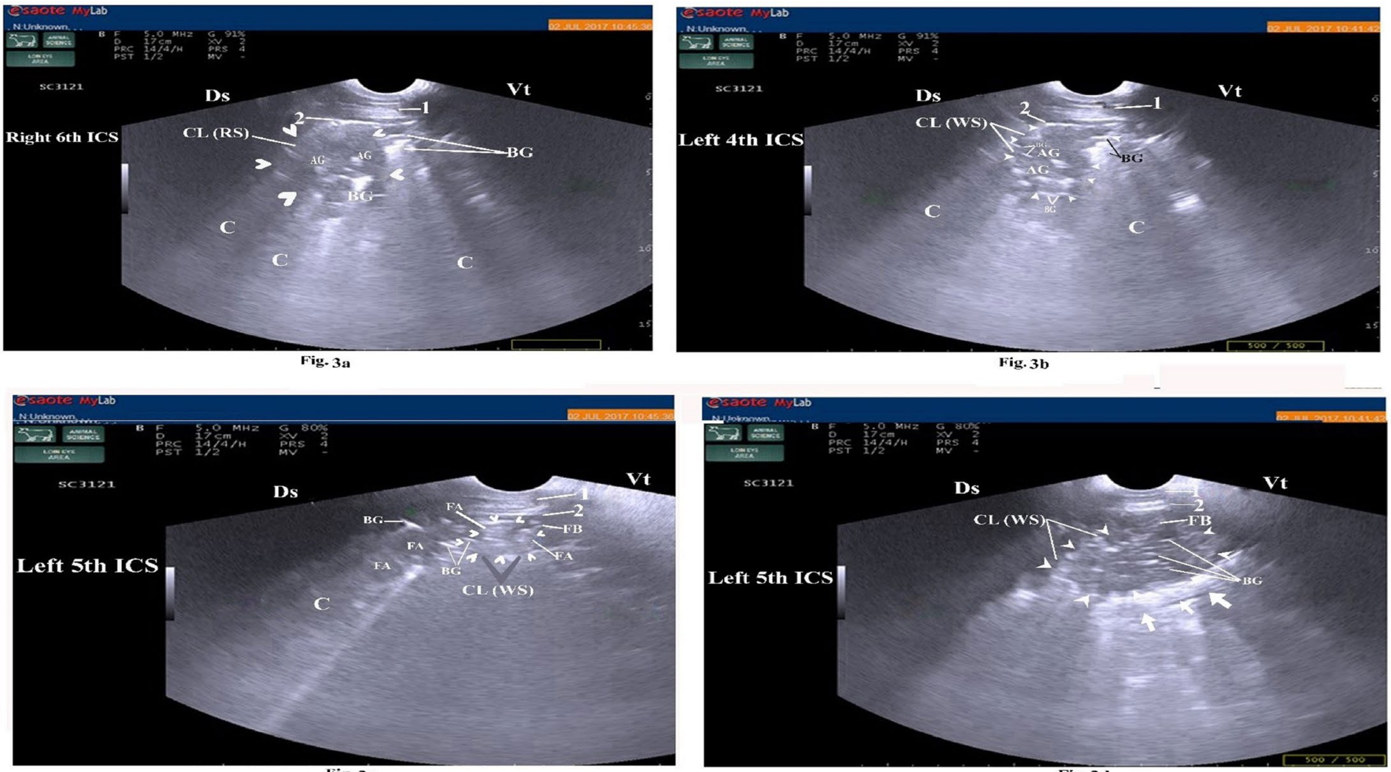

Fig. 3a Fig. 3b Fig. 3c Fig. 3d

Fig. 3. Ultrasonogram in cattle with bronchopneumonia imaged from the middle of the thorax in the right 6th ICS, the left 4th ICS and the left 5th ICS by using 5 MHz convex array transducer. Extensive pulmonary consolidation (CL) (mainly cranioventral lobe of the lung) appeared as heterogeneous rounded-shaped (RS) or wedge-shaped (WS) hypoechoic zones with comet-tail artifacts (C) were seen on the surface of the lung (white head arrows). The hepatized lung parenchyma showed fluid bronchogram (FB) that appeared as an anechoic tubular structure with a hyperechoic wall or as ramified hypoechoic tubular structures. Hyperechoic reflective bands or ramified hyperechoic bands represented bronchoaerograms (BG) with acoustic shadowing (AS) or comet-tail artifacts (C). Superficial fluid alveolograms (FA) were imaged as round hypoechoic to anechoic zones on the surface of the consolidated lung lobules. Hyperechoic zones or hyperechoic spots in hepatized lung parenchyma referred to air alveolograms (AG) were visualized in some consolidated lung areas. Under these consolidated areas of the lung, hyperechogenic regions are visible that correspond to inclusions of air (white arrows). 1, Thoracic wall; 2, Pleura; Ds, Dorsal; Vt, Ventral.

malities were visible on the surface of the lungs or superficial part of the lung, particularly in the cranioventral lobes, as several individual round hypoechoic zones (Figs. 5a, b) or several hypoechoic areas of variable size and shape with COMT upon sonography (Fig. 3c). Under these consolidated areas of the lung hyperechogenic regions are visible that correspond to inclusions of air (Figs. 3c, 5a).

Lung consolidation or consolidated pulmonary lobes in diseased cattle with bronchopneumonia characterized ultrasonographically with visualization of different forms of bronchograms and alveolograms such as fluid bronchograms, air bronchograms (bronchoaerograms, positive bronchogram), fluid alveolograms and reduced air-filled alveoli. Fluid bronchogram (liquid-filled bronchus in the consolidated lung tissue) was a structure observed with pulmonary consolidation (Figs. 3a, b, c), which appeared as an anechoic tubular structure with a hyperechoic wall resembling a blood vessel or as ramified hypoechoic tubular structure (Fig. 3d). Air bronchograms were air-filled bronchi in the compressed pulmonary tissue (within consolidated pulmonary lobe) appeared as hyperechoic reflective bands, echogenic linear bands with branches (ramified hyperechoic bands) with acoustic shadowing or COMT (Figs. 3c, 3d, 4, 5a) where air was trapped in larger bronchi. Superficial fluid alveolograms were fluid-filled alveoli and were imaged as round hypoechoic to anechoic zones on the surface of the consolidated lung lobules (Fig. 5b) where they represented superficial fluid alveolograms with COMT. Air alveolograms (air-filled alveoli) were visualized in some consolidated lung areas as they appeared as hyperechoic zones or hyperechoic spots in hepatized lung parenchyma particularly in severe cases (Figs. 3b, 3c, 4). Regarding to the size of the compressed lung area, the duration of the existence of a consolidation, the amount of fluid filled the alveoli and number of alveoli devoid of air, a reduction of these hyperechoic zones was detected.

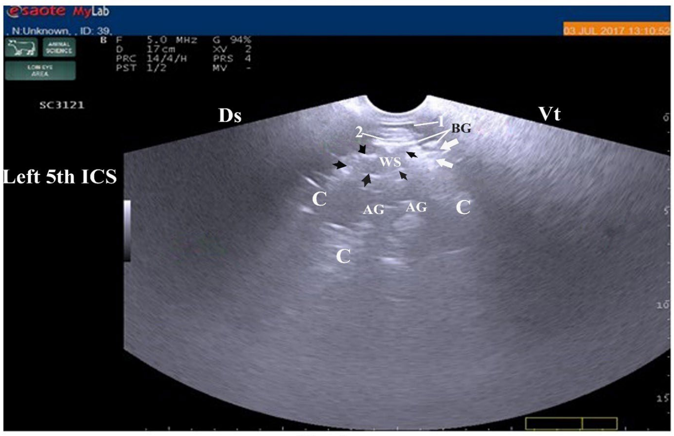

Fig. 4

Fig. 4. Ultrasonogram in a 1 years-old cow-heifer with severe bronchopneumonia (caudal aspect of cranial lobe) imaged from the upper third of the thorax in the left 5th ICS by using 5 MHz convex array transducer. It showed consolidated lung vs. mirror-image. Consolidated lung tissue can be difficult to differentiate from mirror-image artifact. In consolidated lung (CL), there are often small pockets of gas remaining, seen as small hyperechoic areas, which cast an acoustic shadow (white arrow). Consolidated cranial pulmonary lobe appeared (black arrows) as wedge-shaped shaped (WS) hypoechoic, and often heterogeneous zones with comet-tail artifacts (C) were seen on the surface of the lung. Air bronchograms (BG) appeared as hyperechoic reflective bands within consolidated pulmonary lobe with comet-tail artifacts (C). Air alveolograms (AG) were visualized as hyperechoic zones or hyperechoic spots in hepatized lung parenchyma. 1, Thoracic wall; 2, Pleura; Ds, Dorsal; Vt, Ventral.

Diseased cattle with pulmonary emphysema (n=8) was diagnosed based on clinical examination as increased resonance as well as enlarged lung field upon percussion with reduced vesicular breath sounds. Ultrasonographically, pulmonary emphysema was characterized by numerous COMT that were imaged as echogenic, closely situated echo bands starting at the surface of lung and running perpendicular to the pleura in the lung. The mild cases of pulmonary emphysema showed few COMT in the form of few echogenic bands run from the lung surface (Fig. 6a), hence, severe cases of pulmonary emphysema showed numerous COMT in the form of multiple bright echogenic bands extending at the lung surface and running perpendicular to the pleura (Fig. 6b). The reverberation artifacts found in healthy lung tissue were no longer visible. The context of bronchopneumonia, consolidations could partly not be identified in case of pulmonary emphysema due to numerous COMT.

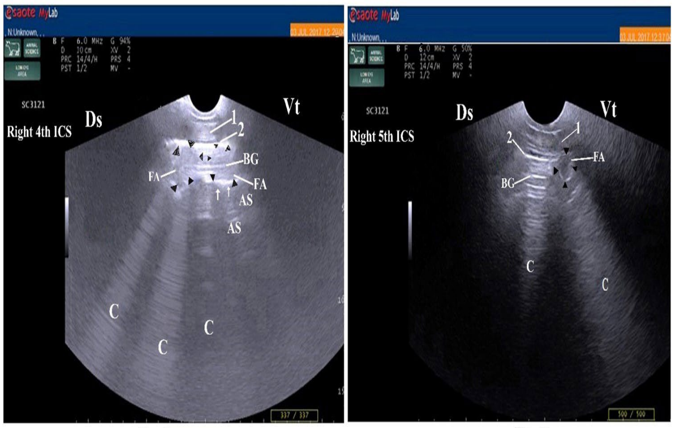

Fig. 5a Fig. 5b

Fig. 5. Ultrasonogram in a 3 months-old cattle-calf with aspiration pneumonia imaged from the upper third of the thorax in the right 4th ICS [Fig. 5a] (caudal aspect of cranial lobe) and from the middle of the thorax in the right 5th ICS [Fig. 5b] (middle lobe) by using 6 MHz micro convex array transducer. It showed mild abnormalities were visible on the surface of the lungs as several individual round hypoechoic zones (black head arrows) with comet-tail artifacts (C), bronchoaerograms (BG) and fluid alveolograms (FA) within localized consolidated pulmonary lobes (CL). Under these consolidated areas of the lung, hyperechogenic regions were visible that correspond to inclusions of air (white arrows). BG were imaged as hyperechoic reflective bands with acoustic shadowing (AS) while FA appeared as round hypoechoic to anechoic zones on the surface of the consolidated lung lobules (Fig. 5b) with comet-tail artifacts (C). 1, Thoracic wall; 2, Pleura; Ds, Dorsal; Vt, Ventral.

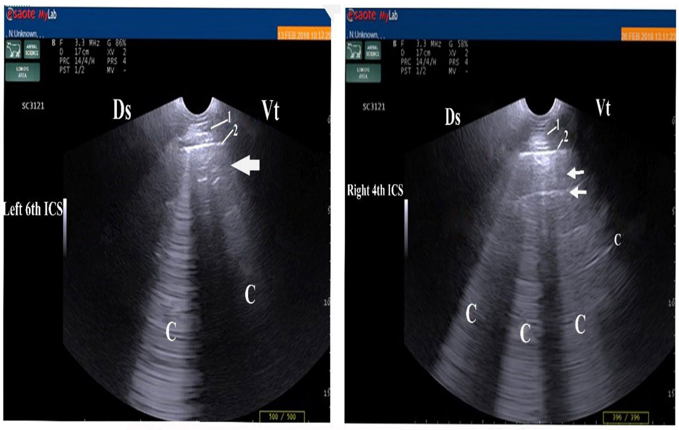

Fig. 6a Fig. 6b

Fig. 6. Ultrasonogram of lung in cattle with pulmonary emphysema by using 3.3 MHz convex array transducer. Fig. 6a, a mild case of pulmonary emphysema (caudal lobe) in 2 years-old cow-heifer imaged from the middle part of the thorax in the left 6th ICS. It showed few comet-tail artifacts (C) in the form of bright, closely situated echogenic bands (white arrows) starting at the lung surface and running perpendicular to the pleura in the lung tissue. Fig. 6b, a severe case of pulmonary emphysema (caudal aspect of cranial lobe) in 2 years-old cow-bull imaged from the middle part of the thorax in the right 4th ICS showed numerous comet-tail artifacts (C) in the form of multiple bright echogenic bands (white arrows) extending at the lung surface and running perpendicular to the pleura. The reverberation artifacts found in healthy lung tissue were no longer visible in case of pulmonary emphysema. 1, Thoracic wall; 2, Pleura; Ds, Dorsal; Vt, Ventral. comet-tail artifacts.

In case of pleurisy and pleural effusions, the diseased cattle (n=4) had the clinical findings of a reduced resonance on percussion of the chest with pleurodynia. The affections were bilateral. Ultrasonographically, the two pleura separated from one another forming pleural cavity with accumulations of hypoechoic to anechoic fluids or a liquid-like contents (pleural effusions) located in the pleural cavity with acoustic enhancement deep to the lesion. Echogenic bands were seen in the hypoechoic or anechoic fluids (Figs. 7a). The fluid led to compression atelectasis in the cranial lobes, and where air was trapped in larger bronchi, they were hyperechoic with COMT (Fig. 7b). In some cases of cases of pleurisy and pleural effusions, the lung tissue was displaced so far from the thoracic wall as well as the heart was also dislocated from the chest wall and compressed, therefore, they were no longer visible ultrasonographically.

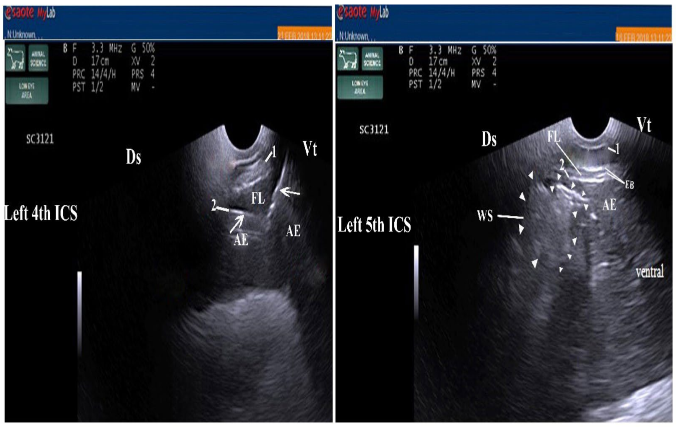

Fig. 7a Fig. 7b

Fig. 7. Ultrasonogram of lung in cattle with pleurisy and moderate pleural effusions (PE) by using 3.3 MHz convex array transducer. Fig. 7a, a 3 years-old non pregnant cow imaged from the middle part of the thorax in the left 4th ICS; Fig. 7b, a 1.5 years-old cow-heifer imaged from the middle part of the thorax in the left 5th ICS. Pleural effusions appeared as anechoic [Fig. 8a] or hypoechoic [Fig. 8b] fluid deposits (FL) between the visceral and parietal pleura with acoustic enhancement deep to the lesion (AE); the lung with its irregular appearing surface (white arrows) is displaced from the chest wall by the hypoechoic fluid (FL). Beneath that, a wedge-shaped consolidated zone (WS) was imaged within the lung tissue (white head arrows), which caused dimpling of the visceral pleural surface of the lung and in which vessel structures were visible; echogenic bands (EB) were seen within the fluid deposits (FL). 1, Thoracic wall; 2, Pleura; Ds, Dorsal; Vt, Ventral.

DISCUSSION

BRD was the most common and severe disease in calf and dairy heifers (khalphallah *et al.*, 2016a, 2016b; Hussein *et al.*, 2018; Cuevas-Gómez *et al.*, 2020; Mahendran, 2020). The clinical findings in investigated cattle with respiratory affections through the present study were characteristics either for U_RG or L_RG. These findings were in agreement with Ollivett and Buczinski (2016); Buczinski *et al.* (2014); Buczinski *et al.* (2015); Timsit *et al.* (2016); Mahendran (2020). Furthermore, calves also showed very few clinical signs at the time of fever detection. These factors combined suggested a high rate of false positive identification (low specificity) for BRD through fever detection alone (Mahendran, 2020). The current study showed characteristic findings for each separated group were reported. Tachycardia, harried respiratory movement, accelerated respiratory rate and reduced ruminal motility were more pronounced with L_RG whereas enlarged larynx and swollen submaxillary lymph nodes were mostly common with U_RG. The abnormal tracheal sounds were heard only with U_RG, hence, the abnormal lung sounds were heard only with L_RG. Flöck (2004) added that Where aspiration pneumonia was suspected upon physical examination that revealed a history of dyspnoea, foul-smelling breath, outstretched posture of the head and neck. These findings confirm those of the current study that revealed foul-smelling nasal discharges, pleurodynia and expiratory grunting were notable only with L_RG particularly pleurisy and aspiration pneumonia. on other hand, Cuevas-Gómez *et al*. (2020) confirmed the poor correlations between calf clinical signs and the simultaneous presence of lung consolidation. The most frequent clinical disorders associated with BRD were nasal discharge at days 0 and 7 post-arrival and fever at days 7 and 14 post-arrival. The rest of the other clinical signs had a low prevalence during the first 28 days. Similar results reported by Khalphallah *et al*. (2016a, 2016b) who added that clinical findings for the diseased dairy heifers with BRD complex varied according to the sampling day. The severity of the clinical signs was aggravated until day 7 after treatment. However, the clinical signs typically disappeared gradually at day 22 following treatment.

Thus, changes in blood neutrophil number and N: L might be useful indicators of respiratory disease in calves that developed lung consolidation following natural infection (Cuevas-Gómez *et al*., 2020). Therefore, the present study revealed that the whole blood pictures indices including RBCs, Hb and PCV showed no significant changes either between the control group and each of U_RG and L_RG, or between the two diseased groups except for TLC and DLC. They were within the reference ranges reported by Radostits *et al*. (2000); Jackson and Cockcroft (2002); Smith (2009). Šoltésová *et al*. (2015) reported we found leukocytosis and significantly higher Hb concentrations of Hb as well as higher values of RBCs. PCV and main corpuscular volume displayed no changes between both groups of calves. On the other hand, Cuevas-Gómez *et al*. (2020) contradicted these findings whereas calves with clinical BRD and lung consolidation (BRD-con calves) had lower RBC number than healthy calves.

The upper and lower respiratory tract diseased groups reported significant elevations in plasma fibrinogen concentrations when comapring with their values in control cattle. The significant changes in TLC, neutrophils and plasma fibrinogen levels were not observed between U_RG and L_RG, however, their levels were higher than the reference ranges reported by Jackson and Cockcroft (2002); Smith (2009). Plasma fibrinogens levels was also considered a strong marker of bacterial infection and inflammatory process in domestic ruminants (Youssef *et al*., 2015). Garry (1984) confirmed that that elevated plasma fibrinogen levels could be applied as an indicator of poor prognosis in calves with bacterial bronchopneumonia. Abdelbaset *et al*. (2014) also confirmed that serum Hp and plasma fibrinogen levels were good indicators for the inflammatory conditions of the lungs in buffaloes especially in case of fibrinous bronchopneumonia, bronchiolitis and emphysema and broncho-interstitial pneumonia. Serum Hp and plasma fibrinogen levels were not affected in case of pulmonary congestion and edema.

Hp was one of the major APPs that was extensively studied in cattle (Schrodl *et al*., 2016). Regarding to the present study, serum Hp concentrations were significantly ($p<0.05$) increased in U_RG and L_RG comparing to their values in control animals. These remarkable changes were not described between U_RG and L_RG. Serum levels of Hp in cattle with respiratory affections were higher than their reference ranges reported by Nazifi *et al*. (2008); Jain *et al*. (2011). These results agreed with Tóthová *et al*. (2013a); Abdelbaset *et al*. (2014); El-Deeb and Elmoslemany (2016); Joshi *et al*. (2016). Increased Hp level might be a consequence of severe tissue injury caused by inflammation occurring in calves in BRD (El-Deeb and Elmoslemany, 2016; Joshi *et al*., 2016). The other literature supported the high response of Hp levels to change due to therapy in BRD whereas Hp increased immediately after infection particularly with BRD even in mild to moderate infection, therefore Hp as an AAP was more sensitive than the other AAPs under field conditions as it was rapidly increased in serum even in mild to moderate infection. Thus, Hp might be a preferred biomarker in BRD and other respiratory infections in buffaloes (Abdelbaset *et al*., 2014; El-Deeb and Elmoslemany, 2016; Joshi *et al*., 2016).

U_RG and L_RG showed significant elevations in serum concentrations of total proteins and globulins whereas A/G ratio was significantly reduced comparing to their values in control cattle. These results supported by Šoltésová *et al*. (2015); Başbuğ *et al*. (2016); Metwally *et al*. (2017); Kumar *et al*. (2018); Anwar *et al*. (2019). Alterations in protein profiles i.e. hyperproteinemia, hyperglobulinemia and reduce A/G ratio in BRD that usually was related to infection and inflammation corresponded to changes occurred during acute phase response. Hyperproteinemia was attributable to elevated synthesis of APPs, complement proteins and immunoglobulins. The significant reduction in A/G values was as a result to the increased immunoglobulin synthesis (due to the immune system stimulation) following antigenic stimulation (as a result of the infectious agents) (Evans 2005; Tóthová *et al*. 2013b; Anwar *et al*. 2019). These remarkable changes (significant elevations) in serum total proteins and globulins were not detected between U_RG and L_RG. Their serum concentrations in diseased cattle were within their reference ranges reported by Rosenberger (1990); Radostits *et al*. (2000); Jackson and Cockcroft (2002); Smith (2009). Serum albumins levels were not significantly changed either in the two diseased group when compared with the control animals or between U_RG and L_RG when their values were compared with each other. These results were matched with Başbuğ *et al*. (2016); Metwally *et al*. (2017); Anwar *et al*. (2019). This decrease in serum albumin in BRD as the most negative APPs, might be attributed to liver as it might have stopped synthesis of Albumin in consistent with increase the production of Hp and SAA (Başbuğ *et al*., 2016). This interpretation was supported by Šoltésová *et al*. (2015) who mentioned that serum albumin was the major negative APP. During the acute phase response, the request for amino acids for production of the positive APPs was significantly elevated, which necessitated reprioritization of hepatic protein synthesis. It had been reported that during the acute phase response 30–40% of hepatic protein anabolic capacity was used for the production of positive APPs; thus, the production of other proteins required to be curtailed which produced hypoalbuminemia. Tóthová *et al*. (2012, 2013b) showed that not only acute respiratory tract diseases but also chronic cases were characterised with increased some APPs production and remarkable changes in serum protein profile characterized by hypoproteinaemia, hyperglobulinemia and hypoalbuminemia as well as lower albumin-globulin ratio.

Regarding to the previous reports, BRD affected calves showed significant increase in serum activities of ALT and AST when compared to healthy control calves (Almujalli *et al*., 2015; Metwally *et al*., 2017; Kumar *et al*., 2018; Anwar *et al*., 2019). On other hand, the current study reported that the lipid profiles were clearly changed in cattle with respiratory affection either for U_RG or L_RG whereas remarkable elevations in serum concentrations of cholesterol, triglycerides, HDL, VLDL and ALT as well as remarkable reductions in serum levels of LDL and AST were reported in both U_RG or L_RG when their values compared with those in control group. No significant changes for blood lipid profiles were observed between U_RG and L_RG. In contrast, Khalphallah *et al*. (2016b) mentioned that serum concentrations of total cholesterol and triglycerides showed no remarkable changes in Holstein dairy heifers infected with respiratory syncytial virus during the acute phase at day 0 before treatment compared with the post convalescent phase at day 50 after therapy. Furthermore, Civelek *et al*. (2007) stated a marked drop of blood total cholesterol and HDL-c levels, accompanied by significant elevation of serum levels of VLDL-c and triglycerides of bronchopneumonic calves were reported in septic patients (Amersfoort *et al*., 2003) and neonatal calves (Civelek *et al*., 2007). The reduction in serum cholesterol in pneumonic calves could be attributed either to inflammatory processes and subsequent alterations in lipoprotein metabolism or hepatic dysfunction (Civelek *et al*., 2007). Lower level of LDL-c might be attributed to its protective effects against inflammation which mediated through bacterial endotoxins binding and subsequent neutralization (Wu *et al*., 2004). It was confirmed that inflammation was associated with hypertriglyceridemia in both animals and humans (Phetteplace *et al*., 2000). This might be due to an increased production of VLDL-c, reduced conversion of VLDL-c to LDL-c by the inhibition of lipoprotein lipase activity

(Gouni *et al*., 1993) or stimulation of hepatic and adipose tissue lipolysis as well as hepatic fatty acid synthesis, which served as substrates for hepatic VLDL synthesis (Feingold *et al*., 1992). On the other hand, the previous articles revealed that higher activity of serum AST and ALT in pneumonic calves or BRD affected calves probably originated from increased respiratory rate and prolonged muscle work during prolonged duration or severe cases of bovine respiratory diseases or might be cooperated with possible hepatic dysfunction convinced by inflammatory response in pneumonic calves (Almujalli *et al*., 2015; Šoltésová *et al*., 2015). Moreover, the present study notified that the serum concentrations of estimated lipid profiles in all investigated animals either healthy, U_RG or L_RG, were within the reference ranges that had been reported by Morrow *et al*. (1979); Radostits *et al*. (2000); Jackson and Cockcroft (2002); Kaneko *et al*. (2008); Smith (2009).

The evaluation of clinical respiratory signs, which was widely used as a BRD diagnostic method in feedlots (Leruste *et al*., 2012), was used in conjunction with thoracic ultrasonography, a measure of the presence of lung consolidation. The thoracic ultrasonography method as a novel technique could be used for the early detection of BRD but was rarely used in feedlot studies to date (Abutarbush *et al*., 2012; Timsit *et al*., 2019; Cuevas-Gómez *et al*., 2020). In the present study, it was noticed that the normal lung in healthy cattle could not be imaged due to its air content but reverberation artifacts in the form of echoic bands running parallel to the lungs surface were visible. The visceral pleura (pulmonary) and the lung surface form a hyperechogenic line known as the pleural line. These findings were in agreements with Babkine and Blond (2009); Adams and Buczinski (2016); Ollivett and Buczinski (2016); Braun *et al*. (2020). Invisualization of normal lung by using ultrasonography was as a result to Air contained in the lung tissue blocks the progression of the ultrasound waves, which caused reverberation artifacts. As a result, normal air-filled pulmonary tissue was imaged (Babkine and Blond, 2009). Moreover, Flöck (2004) mentioned that the motion of the lungs synchronous with respiration was visible with both high frequency and low frequency transducers.

Ultrasonographic findings in cattle with respiratory diseases were diagnostic and useful in differentiation between the upper and lower respiratory tract affections. They also were helpful in categorization different pulmonary affections. The current study classified the upper respiratory diseases [U_RG] (42.01%) as well as the bronchial and pulmonary affections [L_RG] (57.97%) based on the ultrasonographic findings through estimating the percentages and prevalence rate of each affection. Out of forty cattle [L_RG], the pulmonary affections included bronchopneumonia (n=16), lung consolidation (n=12), pulmonary emphysema (n=8) and pleura effusions and pleurisy (n=4). On the hand, the previous studies mentioned that when a systematic clinical score, such as the Wisconsin Respiratory Score,1 was also incorporated, calves was categorized by BRD subtypes, including upper respiratory tract infections, subclinical pneumonia and clinical pneumonia (Ollivett and Buczinski 2016). The current study considered that thoracic ultrasonography is an important diagnostic tool in cows with respiratory diseases because it determined the location and extent of the lung lesions as well as the severity of the affection. These results supported by Buczinski *et al*. (2014) who revealed that ultrasonography could be a useful method to detect the extent of lung lesions in calves with or without typical acute clinical signs of BRD. Interestingly, subclinical pneumonia also might be detected in well-managed dairy herds without previous history of BRD in replacement calves.

Regarding to U_RG, the ultrasonographic findings revealed healthy normal sonographic appearance of the lung, pleura and bronchi. No characteristic abnormal findings were visualized. Normal lung was characterized by observation of a hyperechoic line with reverberation artifact, indicative of the normal pleural interface that agreed with Blond and Buczinski (2009); Cramer and Ollivett, (2019). In this context, upper respiratory infection was defined as a positive respiratory score and a normal thoracic ultrasonography whereas clinical pneumonia was characterized by a positive respiratory score and abnormal thoracic ultrasonography. Subclinical pneumonia had a normal respiratory score and an abnormal thoracic ultrasonography (Ollivett and Buczinski, 2016).

The clinical signs did not represent accurate indicators of lung consolidation, and thus making it necessary to use thoracic ultrasonography to detect lung consolidations antemortem (Cuevas-Gómez *et al*., 2020). The current study stated that the sonographic diagnosis of pulmonary parenchymal consolidation in cattle with L_RG was based upon the detection of hypoechoic pulmonary parenchyma and bronchograms or vessels seen within it. Consolidation was observed most often cranioventral. These results were supported by Babkine and Blond (2009); Ollivett and Buczinski (2016); Braun *et al*. (2020). Buczinski *et al*. (2016) added that thoracic auscultation was sensitive (72.9%), but not specific (53.3%) to diagnose bronchopneumonia. Therefore, thoracic ultrasonography was more specific (92.9%) than thoracic auscultation (53.3%) in bronchopneumonia diagnosis. Adding thoracic ultrasonography with thoracic auscultation significantly enhanced the accuracy of bronchopneumonia diagnosis. In the present study, L_RG showed several characteristic ultrasonographic findings that described several thoracic affections. In cattle with bronchopneumonia, the ultrasonographic images were variables as complete (extensive) lung consolidations in case of severe persistent chronic bronchopneumonia or partial (localized) lung consolidations in case of less severe chronic bronchopneumonia were reported. Extensive pulmonary consolidation in which the whole cranioventral pulmonary lobe (cranioventral portions of the main lung lobes) was affected, appeared as rounded or wedge-shaped shaped hypoechoic, and often heterogeneous zones with COMT were seen on the surface of the lung, in the cranioventral lobe of the lung. These extensive hypoechoic zones resembling liver parenchyma without reverberation artifacts were seen and were well demarcated from healthy tissue. The anechoic areas represent fluid-filled or necrotic areas. These results were in agreement with Ollivett and Buczinski (2016); Braun *et al*. (2020). In the current work, lung consolidations in some diseased cases with bronchopneumonia and/or aspiration pneumonia imaged as echogenic regions with COMT. These Extensive changes (consolidations) were particularly evident in the cranioventral lung fields as well as in individual areas of the dorsal lung, in otherwise physiologically normal lung tissue. These results were supported by Rabeling *et al*. (1998); Babkine and Blond (2009); Ollivett *et al*. (2013); Ollivett *et al*. (2015); Ollivett and Buczinski (2016); Braun *et al*. (2020). Consolidation was visualized most often cranioventrally, whereby the right lung was usually severely affected (Reef, 1998). A majority of calves with ultrasonographic evidence of lung consolidation were not previously diagnosed as sick by the producers (Buczinski *et al*., 2014). In the current work, Hepatisation of lung parenchyma in cattle with L_RG occurred with bronchopneumonia and severe pulmonary consolidation, resulting in an ultrasonographic appearance similar to that of a liver. The extensive hypoechoic zones resembling liver parenchyma without reverberation artifacts were seen and were well demarcated from healthy tissue. Within the hypoechoic zones were disseminated hyperechoic and anechoic dot-shaped as well as some branched line-shaped structures and also tubular structures with walls of varying echogenicity and ramification towards the lung periphery with hypoechoic to hyperechoic content. These results were supported by Ollivett and Buczinski (2016); Braun *et al*. (2020). In chronic lung affections, the air content in the compressed areas could be completely nullified, therefore, only the homogeneous-echoic texture of the hepatized lung remained. In cattle calves with bronchopneumonia with pulmonary consolidations, where the lung tissues appeared hypoechoic and their echo texture might look like liver parenchyma containing bronchoaerograms in this region. Sometimes, hyperechoic reflective bands of an air-filled bronchus were detected in the lung area resembling liver parenchyma, representing air bronchograms (Jung and Bostedt, 2004; Ollivett *et al*., 2015; Ollivett and Buczinski, 2016; Buczinski *et al*., 2016).

According to the current results, pulmonary consolidation was localized, as in the case of aspiration pneumonia. When aspiration pneumonia was suspected, mild abnormalities were visible on the surface of the lungs or superficial part of the lung, particularly in the cranioventral lobes, as several individual round hypoechoic zones or several hypoechoic areas of variable size and shape with COMT upon sonography. Under these consolidated areas of the lung hyperechogenic regions were imaged that corresponded to inclusions of air. Furthermore, these results were confirmed by Flöck (2004); Babkine and Blond (2009); Braun *et al.* (2020) who said that pulmonary consolidation might affect the whole ventral part of a pulmonary lobe or might be localized, as in the case of aspiration pneumonia. The other literature added that compared to physiologically ventilated lung, in amniotic fluid aspirations there was reduction and blurring of the reverberation artifacts, as well as an increased distance between the individual repeating echoes in the lung. Comet tail artifacts sometimes were visualized in poorly ventilated parts of the lung, extending from the pleura. In all calves with amniotic fluid aspiration, the transparency of the entire lung was reduced due to the reduced pulmonary air content, which was reflected by indistinctness of the reverberation artifacts in the sonogram. Severe amniotic fluid aspirations, which are associated with atelectases or dystelectases, were characterized by reduced reverberation artifacts with occasional comet tail artifacts in the other lung fields (Jung and Bostedt, 2004; Babkine and Blond, 2009; Braun *et al.*, 2020).

Lung consolidation or consolidated pulmonary lobes in diseased cattle with bronchopneumonia in L_RG characterized ultrasonographically with visualization of different forms of bronchograms and alveolograms such as fluid bronchograms, air bronchograms (bronchoaerograms, positive bronchogram), fluid alveolograms and reduced air-filled alveoli. On other hand, ultrasonographic appearance of lung consolidations not the only ultrasonographic indicator of respiratory disease. Superficial alveologram, B-lines and pleural fragmentation were also found in cases of pneumonia (viral or bacterial) (Volpicelli, 2013; Buczinski *et al.*, 2015). In L_RG, fluid bronchogram as a structure observed with pulmonary consolidation representing fluid filled bronchi, appeared as an anechoic tubular structure with a hyperechoic wall resembling a blood vessel or as ramified hypoechoic tubular structure. These results were confirmed by Flöck (2004); Jung and Bostedt (2004); Babkine and Blond (2009); Ollivett and Buczinski (2016); Braun *et al.* (2020). In cases of infection, a dynamic bronchogram could be observed if a gas/tissue interface moved during breathing. In cases of obstructive atelectasis, the observed bronchogram was static and did not change in relation to breathing movements. Furthermore, the observation of a dynamic bronchogram was of a sensitivity 61% and a specificity 94% for detecting pneumonia (Lichtenstein *et al.* 2009). In agreement with Ollivett and Buczinski (2016); Braun *et al.* (2020), air bronchograms (bronchoaerograms) as air-filled bronchi within consolidated pulmonary lobe in cattle with in L_RG, appeared as hyperechoic reflective bands or echogenic linear bands with branches (ramified hyperechoic bands) with acoustic shadowing or COMT where air was trapped in larger bronchi. Superficial fluid alveolograms (fluid-filled alveoli) were imaged in the current study as round or circular hypoechoic to anechoic zones on the surface of the consolidated lung lobules with COMT. These finds were in agreements with Babkine and Blond (2009); Cuevas-Gómez *et al.* (2020). It was noticed that air alveolograms (air-filled alveoli) were visualized in some consolidated lung areas in L_RG as they appeared as hyperechoic zones in hepatized lung parenchyma particularly in severe cases. These results were supported by Jung and Bostedt (2004); Hussein *et al.* (2018); Braun *et al.* (2020). In consistent with the previous report (Reef, 1991; Schneider, 1995), the current study reported that regarding to the size of the compressed lung area, the duration of the existence of a consolidation, the amount of fluid filled the alveoli and number of alveoli devoid of air, a reduction of these hyperechoic zones (air alveolograms) was detected in L_RG. In cattle and horse, Reef (1998); Scott (1998) revealed that the replacement of alveolar air with fluid made the lung tissue to be imaged hypoechoic. The irregularity of the visceral pleural surface of the lung as a result to unbalanced air content of the lung periphery might be a first sign of consolidation. COMT radiated from these non-aerated areas, originated from small accumulations of blood, exudates, mucus, oedema fluid, or tumour cells or from scarring following a previous bout of pneumonia or pleurisy. These small superficial hypoechoic areas were homogeneous, consistent with superficial fluid alveolograms (Reef, 1998; Scott, 1998; Flöck, 2004). The hypoechoic zones in the cranioventral lung areas and the cranioventral portions of the main lobes turned out to be consolidated lung tissue, that were largely devoid of air as a result of atelectasis caused by an obstruction, were named as superficial fluid alveologram (Flöck, 2004; Jung and Bostedt, 2004; Babkine and Blond, 2009).

Pulmonary emphysema was diagnosed through the current study as one of L_RG affections based on clinical examination as increased resonance as well as enlarged lung field upon percussion with reduced vesicular breath sounds. Ultrasonographically, numerous COMT in the form of bright, closely situated echo bands starting at the lung surface and running perpendicular to the pleura in the lung tissue were visualized upon ultrasonography. The mild cases of pulmonary emphysema showed few COMT in the form of few echogenic bands run from the lung surface, hence, severe cases of pulmonary emphysema showed several COMT in the form of multiple echogenic bands extending at the lung surface and running perpendicular to the pleura. The reverberation artifacts found in healthy lung tissue were no longer visible in case of pulmonary emphysema. The context of bronchopneumonia, consolidations could partly not be identified in case of pulmonary emphysema due to numerous COMT. These results were matched with Braun (1997); Flöck (2004); Braun *et al.* (2020). The inability to display the valve level of the heart was reported in three animals had been examined for pulmonary emphysema (Flöck, 2004; Braun *et al.*, 2020). COMT were frequently visualized in healthy calves and in two animals with pulmonary emphysema had at least 1 thoracic ultrasonographic site with this artifact (Buczinski *et al.*, 2014). In human medicine (Reißig and Kroegel, 2003) as well as in previous work in cattle (Flöck, 2004), diffuse COMT were associated with diffuse parenchymal lung diseases such as emphysema. Buczinski *et al.* (2014) suggested that these COMT could also be imaged without lung consolidation or clinical score compatible with BRD. Hussein *et al.* (2018) added that in calves with pulmonary emphysema, the ultrasonographic examination of chest in mild cases of pulmonary emphysema displayed few echogenic bands run from the lung surface with reverberation artifacts, hence, severe cases of pulmonary emphysema showed numerous COMT in the form of multiple echogenic bands extending at the lung surface and running perpendicular to the pleura. These COMT ranged from 3 to 4 in number. The most affected lung lobes were the intermediate, then the cranial lobes.

According to the present study, L_RG with pleurisy and pleural effusions had the clinical findings of a reduced resonance on percussion of the chest with pleurodynia. The affections were bilateral. Ultrasonographically, the two pleura separated from one another forming pleural cavity with accumulations of hypoechoic to anechoic fluids or a liquid-like contents (pleural effusions) located in the pleural cavity with acoustic enhancement deep to the lesion. Echogenic bands were seen in the hypoechoic or anechoic fluids. these results were in agreement with Braun (1997); Babkine and Blond (2009); Braun *et al.* (2020). The fluid in L_RG with pleurisy and pleural effusions led to compression atelectasis in the cranial lobes, and where air was trapped in larger bronchi, they were hyperechoic with COMT. In case of severe cases of pleurisy and pleural effusions, the lung tissue was displaced so far from the thoracic wall as well as the heart was also dislocated from the chest wall and compressed, therefore, they were no longer visible ultrasonographically. According to Braun (1997); Radostits *et al.* (2000), the inflammatory pleural effusion was often detected on only one side in cattle as the pleural cavities did not communicate with one another. However, Flöck (2004) reported that inflammatory effusion was always found on both sides, albeit in different degrees. In two animals with pleurisy, pleural effusions, and pneumonia, the lung tissue could not be evaluated by means of sonography due to the large amount of fluid present (poor penetration) (Flöck, 2004). Atelectasis could be because of compression associated with pleural effusions or could be secondary to airway obstruction with gradual air resorption within the affected part of the lung (Sartori and Tombesi, 2010). The pleura of the atelectatic lung appeared smooth and fine, however, it was often imaged as wave-like in the presence of pneumonia (Rantanen *et al*., 1981; Braun, 1997).

CONCLUSION

Thoracic ultrasonography considered a diagnostic tool in cattle with respiratory diseases, it is in determining the location and extent of the lung lesions as well as the severity of the affection.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

Abdallah, A.A., Abdelaal, A.M., El-Sheikh, A.R., Selim, H., Buczinski, S., 2019. Determination of the dynamics of respiratory diseases using thoracic ultrasonographic examination in preweaned dairy calves. Can. Vet. J. 60, 859-863.

Abdelbaset, A.E., Abd Ellah, M.R., Abd ElGhaffar, S.K., Sadiek, A.H., 2014. Acute-phase proteins in different pathological conditions at the lungs of buffaloes. Comp. Clin. Pathol. 23, 823–828. https://doi.org/10.1007/s00580-013-1696-6

Abutarbush, S.M., Pollock, C.M., Wildman, B. K., Perrett, T., Schunicht, O.C., Fenton, R.K., Hannon, S.J., Vogstad, A.R., Jim, G.K., Booker, C.W., 2012. Evaluation of the diagnostic and prognostic utility of ultrasonography at first diagnosis of presumptive bovine respiratory disease. Can. J. Vet. Res. 76, 23–32.

Adams, E.A., Buczinski, S., 2016. Short communication: Ultrasonographic assessment of lung consolidation postweaning and survival to the first lactation in dairy heifers. J. Dairy Sci. 99 (2), 1465-1470. https://doi.org/10.3168/jds.2015-10260.

Almujalli, A.M., El-Deeb, W.M., Eljalii, E.M., Fouda, T.A., AlBlwy, M., 2015. Clinical, biochemical and bacteriological investigation of pneumonia in calves with special reference to alpha-1-acid glycoprotein response. I.J.V.H.S.R. 3, 60-63. http://dx.doi.org/10.19070/2332-2748-1500015.

Amersfoort, E.S.V., Berkel, T.J.C.V., Kuiper, J., 2003. Receptors, mediators and mechanisms involved in bacterial sepsis and septic shock. Clin. Microbiol. Rev. 7, 379-414. https://doi.org/10.1128/CMR.16.3.379-414.2003.

Anwar, M.R., Abd El-Raof, Y.M., El-Attar, H.M., Hefnawy, A.E., Ghanem, M.M., 2019. Evaluation of clinical and hematobiochemical alterations in naturally occurring bovine respiratory disease in feedlot cattle calves in Egypt. B.V.M.J. 36, 305-313.

Babkine, M., Blond, L., 2009. Ultrasonography of the bovine respiratory system and its practical application. Vet. Clin. North Am. Food Anim. Pract. 25, 633-649. https://doi.org/ 10.1016/j.cvfa.2009.07.001.

Başbuğ, O., Zahid, T.A., Tuzcu, N., 2016. Tumour necrosis factor-alpha, haptoglobin, serum amyloid A and neopterin levels in cattle with lumpy skin disease. Kafkas Universitesi Veteriner Fakultesi Dergisi 22, 417–424. https://doi.org/ 10.9775/kvfd.2015.14896.

Basoglu, A., Sevinc, M., Birdane, F.M., Boydak, M., 2002. Efficacy of sodium borate in the prevention of fatty liver in dairy cows. J. Vet. Int. Med. 16, 732-735. https://doi.org/ 10.1892/0891-6640(2002)016<0732:eosbit>2.3.co;2.

Reißig, A., Kroegel, C. 2003. Transthoracic sonography of diffuse parenchymal lung disease: the role of comet tail artifacts. J. Ultrasound Med. 22, 173-80. https://doi.org/10.7863/jum.2003.22.2.173

Berry, B.A., Confer, A.W., Krehbiel, C.R., Gill, D.R., Smith, R.A., Montelongo, M., 2004. Effects of dietary energy and starch concentrations for newly received feedlot calves. II. Acute-phase protein response. J. Anim. Sci. 82, 845–50. https://doi.org/ 10.2527/2004.823845x.

Blakebrough-Hall, C., McMeniman, J.P., González, L. A., 2020. An evaluation of the economic effects of bovine respiratory disease on animal performance, carcass traits, and economic outcomes in feedlot cattle defined using four BRD diagnosis methods. J. Anim. Sci. 98, 1-11. https://doi.org/10.1093/jas/skaa005.

Blond, L., Buczinski, S., 2009. Basis of ultrasound imaging and the main artifacts in bovine medicine. Vet. Clin. North Am. Food Anim. Pract. 25, 553-565. http://dx.doi.org/10.1016/j.cvfa.2009.07.002.

Braun, U., 1997. Pleura, Lunge und Mediastinum, in: Braun, U. (Ed.), Atlas und Lehrbuch der Ultraschalldiagnostik beim Rind. Berlin, Parey, pp. 115–141.

Braun, U., Föhn, J., Pusterla, N., 1994. Ultrasonographic examination of the ventral neck region in cows. Am. J. Vet. Res. 55, 14-21.

Braun, U., Oschlies, C., Ohlerth, S., Gerspach, C., 2020. Ultrasonography of the lung in calves. Schweiz. Arch Tierheilkd. 162, 513-530. German. https://doi.org/10.17236/sat00269.

Braun, U., Pusterla, N., Flückiger, M. 1997. Ultrasonographic findings in cattle with pleuropneumonia. Vet. Rec. 141, 12–17. https://doi.org/10.1136/vr.141.1.12

Buczinski, S., Forté, G., Francoz, D., Bélanger, A.M., 2014. Comparison of thoracic auscultation, clinical score, and ultrasonography as indicators of bovine respiratory disease in preweaned dairy calves. J. Vet. Intern. Med. 28, 234-42. https://doi.org/10.1111/jvim.12251.

Buczinski, S., Ménard, J., Timsit, E., 2016. Incremental value (Bayesian framework) of thoracic ultrasonography over thoracic auscultation for diagnosis of bronchopneumonia in preweaned dairy calves. J. Vet. Intern. Med. 30, 1396–1401. https://doi.org/10.1111/jvim.14361.

Buczinski, S., Ollivett, T.L., Dendukuri, N., 2015. Bayesian estimation of the accuracy of the calf respiratory scoring chart and ultrasonography for the diagnosis of bovine respiratory disease in pre-weaned dairy calves. Prev. Vet. Med. 119, 227–231. https://doi.org/10.1016/j.prevetmed.2015.02.018.

Carter, J.N., Meredith, G.L., Montelongo, M., Gill, D.R., Krehbiel, C.R., Payton, M.E., Confer, A.W., 2002. Relationship of vitamin E supplementation and antimicrobial treatment with acute-phase protein responses in cattle affected by naturally acquired respiratory tract disease. Am. J. Vet. Res. 63, 1111-1117. https://doi.org/10.2460/ajvr.2002.63.1111.

Cernicchiaro, N., White, B.J., Renter, D.G., Babcock, A.H., 2013. Evaluation of economic and performance outcomes associated with the number of treatments after an initial diagnosis of bovine respiratory disease in commercial feeder cattle. Am. J. Vet. Res. 74, 300–309. https://doi.org/10.2460/ajvr.74.2.300.

Civelek, T., Kav, K., Camkerten, I., Celik, A.H., Acar, A., 2007. Effect of bacterial pneumonia in neonatal calves on serum lipids. Bull. Vet. Inst. Pulawy 51, 503-507.

Cockcroft, P.D., 2015. Diagnosis and clinical reasoning in cattle practice, in: Bovine medicine, third ed. John Wiley and Sons, Hoboken, pp. 124-132.

Coles E.H., 1986. Veterinary Clinical Pathology, fourth 4th ed. W.B. Saunders, Philadelphia, pp. 132-139.

Cramer, M.C., Ollivett, T.L., 2019. Growth of preweaned, group-housed dairy calves diagnosed with respiratory disease using clinical respiratory scoring and thoracic ultrasound-A cohort study. J. Dairy Sci. 102, 4322-4331. https://doi.org/10.3168/jds.2018-15420.

Cuevas-Gómez, I., McGee, M., McCabe, M., Cormican, P., O'Riordan, E., McDaneld, T., Earley, B., 2020. Growth performance and hematological changes of weaned beef calves diagnosed with respiratory disease using respiratory scoring and thoracic ultrasonography. J. Anim. Sci. 98, skaa345. https://doi.org/10.1093/jas/skaa345.

El-Deeb, W.M., Elmoslemany, A.M., 2016. The diagnostic accuracy of acute phase proteins and proinflammatory cytokines in sheep with pneumonic pasteurellosis. Peer J. 4, e2161. https://doi.org/10.7717/peerj.2161.

Evans, N.A., 2005. Tulathromycin: an overview of a new triamilide antimicrobial for livestock respiratory disease. Vet. Ther. 6, 83-95.

Feingold, K.R., Staprans, I., Memon, R.A., 1992. Endotoxin rapidly induces changes in lipid metabolism that produce hypertriglyceridemia: Low doses stimulate hepatic triglyceride production while high doses inhibit clearance. J. Lipid Res. 33, 1765- 1776.

Flöck, M., 2004. Diagnostic ultrasonography in cattle with thoracic disease. Vet. J. 167, 272–280. https://doi.org/ 10.1016/S1090-0233(03)00110-2

Fraunberger, P., Schaefer, S., Werdan, K., 1999. Reduction of circulating cholesterol and apolipoprotein levels during sepsis. Clin. Chem. Lab. Med. 37, 357-362. https://doi.org/10.1515/CCLM.1999.059

Garry, F.B., 1984. Plasma Fibrinogen Measurement: Prognostic Value in Calf Bronchopneumonia? Zentralblatt Für Veterinärmedizin Reihe A 31, 361-369. https://doi.org/10.1111/j.1439-0442.1984.tb01294.x

Gouni, I., Oka, K., Etienne, J., 1993. Endotoxin induced hypertriglyceridemia is mediated by suppression of lipoprotein lipase at a posttranscriptional level. J. Lipid Res. 4, 139-146.

Hay, K. E., Morton, J. M., Clements, A.C.A., Mahony, T.J., Barnes, T. S., 2017. Population-level effects of risk factors for bovine respiratory disease

in Australian feedlot cattle. Prev. Vet. Med. 140, 78–86. https://doi.org/10.1016/j.prevetmed.2017.03.001.
Humblet, M.F., Coghe, J., Lekeux, P., Godeau, J.M., 2004. Acute phase proteins assessment for an early selection of treatments in growing calves suffering from bronchopneumonia under field conditions. Res. Vet. Sci. 77, 41–47. https://doi.org/10.1016/j.rvsc.2004.02.009
Hussein, H.A., Binici, C., Staufenbiel, R., 2018. Comparative evaluation of ultrasonography with clinical respiratory score in diagnosis and prognosis of respiratory diseases in weaned dairy buffalo and cattle calves. J. Anim. Sci. Technol. 60, 29. https://doi.org/10.1186/s40781-018-0187-3.
Jackson, P.G.G., Cockcroft, P.D., 2002. Clinical Examination of Farm Animals. Blackwell Science Ltd, State Avenue, Ames, Iowa, USA, pp. 301-305.
Jain, S., Gautam, V., Naseem, S., 2011. Acute-phase proteins: As diagnostic tool. J. Pharm. Bioallied Sci. 3, 118–127. https://doi.org/10.4103/0975-7406.76489
Joshi, V., Gupta, V.K., Vinodh Kumar, O.R., Pruthvishree, B.S., Dimri, U., Alam, S., 2016. Bovine respiratory disease-an updated review. J. Immunol. Immunopathol. 18, 86–93. https://doi.org/10.5958/0973-9149.2016.00014.9
Jung, C., Bostedt, H., 2004. Thoracic ultrasonographic technique in newborn calves and description of normal and pathological findings. Vet. Radiol. Ultrasound 45, 331–335. https://doi.org/10.1111/j.1740-8261.2004.04063.x
Kaneko, J.J., Harvey, J.W., Bruss, M.L., 2008. Clinical Biochemistry of Domestic Animals, sixth ed. Saunders Elsevier, Philadelphia, pp. 882-888.
Khalphallah, A., Oikawa, S., Motokawa, M., Nakada, K., Aamer, A.A., AbdelAll, Th., 2016a. Serum lecithin:cholesterol acyltransferase activity evaluated as a possible indicator in dairy heifers with suspected bovine respiratory syncytial virus infection. The Japanese Journal of Animal Hygiene 42, 11-18.
Khalphallah, A., Oikawa, S., Motokawa, M., Nakada, K., Hagiwara, K., Aamer, A.A., AbdelAll, Th., Elmeligy, E., 2016b. Nutritional Indicators in Holstein Dairy Heifers Infected with Respiratory Syncytial Virus with Referring to Changes in Lipid Profile, Tumor Necrosis Factor-a and Acute Phase Proteins. Scholar's Adv. Anim. Vet. Res. 3, 22-34.
Kumar, P., Jain, V., Kumar, T., Kumar, V., Rana, Y., 2018. Clinical and Haemato-biochemical Studies on Respiratory Disease in Buffaloes. Int. J. Livest. Res. 8, 178-184. https://doi.org/10.5455/ijlr.20171210043959.
Leruste, H., Brscic, M., Heutinck, L.F., Visser, E.K., Wolthuis-Fillerup, M., Bokkers, E.A., Stockhofe-Zurwieden, N., Cozzi, G., Gottardo, F., Lensink, B. J., van Reenen, C.G., 2012. The relationship between clinical signs of respiratory system disorders and lung lesions at slaughter in veal calves. Prev. Vet. Med. 105, 93–100. https://doi.org/10.1016/j.prevetmed.2012.01.015.
Lichtenstein, D., Mezière, G., Seitz, J. 2009. The dynamic air bronchogram. A lung ultrasound sign of alveolar consolidation ruling out atelectasis. Chest 135, 1421-1425. https://doi.org/10.1378/chest.08-2281
Mahendran, S.A., 2020. Use of fever detection in combination with thoracic ultrasonography to identify respiratory disease, and compare treatments of antimicrobials and NSAID: a randomised study in dairy calves. Vet. Rec. Open 7, e000415. https://doi.org/10.1136/vetreco-2020-000415.
Metwally, A.M., Elshahawy, I.I., Abubaker, Z.M., 2017. Green Tea as a Supportive Treatment for Respiratory Disorders in Calves. Alexandria Journal for Veterinary Sciences 52, 118-144.
Millar, H.R., Simpson, J.G., Stalker, A.L., 1971. An evaluation of the heat precipitation method for the plasma fibrinogen estimation. J. Clin. Pathol. 24, 827-830. https://doi.org/10.1136/jcp.24.9.827.
Morrow, D.A., Hillman, D., Dode, A.W., Kitchen, H., 1979. Clinical investigation of a dairy herd with fat cow syndrome. J. Am. Vet. Med. Ass. 174, 161-167.
Murray, G.M., More, S.J., Sammin, D., Casey, M.J., McElroy, M.C., O'Neill, R.G., Byrne, W.J., Earley, B., Clegg, T.A., Ball, H., Bell, C.J., Cassidy, J.P., 2017. Pathogens, patterns of pneumonia, and epidemiologic risk factors associated with respiratory disease in recently weaned cattle in Ireland. J. Vet. Diagn. Invest. 29, 20–34. https://doi.org/10.1177/1040638716674757.
Nazifi, S., Rezakhani, A., Koohimoghadam, M., Ansari-lari, M., Esmailnezhad, Z., 2008. Evaluation of serum haptoglobin in clinically healthy cattle and cattle with inflammatory diseases in shiraz, a tropical area in southern Iran. Bulg. J. Vet. Med. 11, 95–101.
Ollivett, T., Buczinski, S., 2016. On-farm use of ultrasonography for bovine respiratory disease. Vet Clin Food Anim Pract. 32, 19–35. https://doi.org/10.1016/j.cvfa.2015.09.001.
Ollivett, T., Hewson, J., Schubotz, R., Caswell, J., 2013. Ultrasonographic progression of lung consolidation after experimental infection with Mannheimia haemolytica in Holstein calves. J. Vet. Intern. Med. 27, 673.
Ollivett, T.L., Caswell, J.L., Nydam, D.V., Duffield, T., Leslie, K.E., Hewson, J., Kelton, D., 2015. Thoracic Ultrasonography and Bronchoalveolar Lavage Fluid Analysis in Holstein Calves with Subclinical Lung Lesions. J. Vet. Intern. Med. 29, 1728-1734. https://doi.org/10.1111/jvim.13605.
Panciera, R., Confer, A., 2010. Pathogenesis and pathology of bovine pneumonia. Vet. Clin. North Am. Food Anim. Pract. 26, 191–214. https://doi.org/10.1016/j.cvfa.2010.04.001.
Phetteplace, H.W., Sedkova, N., Hirano, K.I., 2000. Escherichia coli sepsis increases hepatic apolipoprotein B secretion by inhibiting degradation. Lipids 35, 1079-1085. https://doi.org/10.1007/s11745-000-0622-y.
Rabeling, B., Rehage, J., Döpfer, D., Scholz, H., 1998. Ultrasonographic findings in calves with respiratory disease. Vet. Rec. 143, 468-71. https://doi.org/10.1136/vr.143.17.468.
Radostits, O.M., Gay, C.C., Blood, D.C., Hinchcliff, K.W., 2000. Veterinary Medicine: a textbook of the diseases of cattle, horses, sheep, pigs and goats, ninth ed. W.B. Saunders, London, pp. 1819–1822.
Radostits, O.M., Gay, C.C., Hinchcliff, K.W., Constable, P.D., 2007. Diseases of the respiratory system, in: Veterinary medicine: a textbook of the diseases of cattle, horses, sheep, pigs and goats, 10th ed. Saunders Elsevier, Philadelphia, USA, pp. 471–542.
Rantanen, N.W., Gage, L., Paradis, M.R., 1981. Ultrasonography as a diagnostic aid in pleural effusions of horses. Vet. Radiol. 22, 211–216. https://doi.org/10.1111/j.1740-8261.1981.tb01375.x
Reef, V.B., 1991. Equine pediatric ultrasonography. Compound Contin. Educ. 13, 1277–1285.
Reef, V.B., 1998. Thoracic Ultrasonography: Noncardiac Imaging, in: Reef, V.B. (Ed.), Equine Diagnostic Ultrasound. W.B. Saunders, Philadelphia, pp. 187–213.
Reef, V.B., Boy, M.G., Reid, C.F., Elser, A., 1991. Comparison between diagnostic ultrasonography and radiography in the evaluation of horses and cattle with thoracic disease: 56 cases (1984–1985). J. Am. Vet. Med. Assoc. 198, 2112–2118.
Rosenberger, G., 1990. The clinical examination of cattle: 3. In: Dirksen, H.V.G., Gründer, H.D., Stöber, M.S. (Eds.). Paul Parey Publishing House, Berlin and Hamburg, Germany, pp. 670-677.
Sartori, S., Tombesi, P., 2010. Emerging roles for transthoracic ultrasonography in pulmonary diseases. World J. Radiol. 2, 203–214. https://doi.org/10.4329/wjr.v2.i6.203.
Schneider, B., 1995 Vergleichende sonografische und radiologische Untersuchungen bei Lungenerkrankungen des Kalbes. Diss., Hannover.
Schrodl, W., Buchler, R., Wendler, S., Reinhold, P., Muckova, P., Reindl, J., Rhode, H., 2016. Acute phase proteins as promising biomarkers: perspectives and limitations for human and veterinary medicine. Proteomics Clin. Appl. 10, 1077–1092. https://doi.org/10.1002/prca.201600028.
Scott, P.R., 1998. Ultrasonographic examination of the bovine thorax. Cattle Practice 6, 151–153.
Smith, B.P., 2009. Large animal internal medicine, fourth ed. Elsevier, Mosby, Missouri, St. Louis, USA, pp.1824-1825.
Šoltésová, H., Nagyová, V., Tóthová, C., Nagy, O., 2015. Haematological and blood biochemical alterations associated with respiratory disease in calves. Acta Vet. Brn. 84, 249-256.
Timsit, E., Dendukuri, N., Schiller, I., Buczinski, S., 2016. Diagnostic accuracy of clinical illness for bovine respiratory disease (BRD) diagnosis in beef cattle placed in feedlots: A systematic literature review and hierarchical Bayesian latent-class meta-analysis. Prev. Vet. Med.135, 67–73. https://doi.org/10.1016/j.prevetmed.
Timsit, E., Tison, N, Booker, C.W., Buczinski, S., 2019. Association of lung lesions measured by thoracic ultrasonography at first diagnosis of bronchopneumonia with relapse rate and growth performance in feedlot cattle. J. Vet. Intern. Med. 33, 1540–1546. https://doi.org/10.1111/jvim.15483.
Tóthová, Cs., Nagy, O., Kováč, G., 2013a. Chapter 1 – the use of acute phase proteins as biomarkers of diseases in cattle and swine. In. Janciauskiene S (ed), Immunology, Allergology and Rheumatology. In Tech., Slovakia. pp. 103–138. https://doi.org/10.5772/55857.
Tóthová, Cs., Nagy, O., Kováč, G., 2013b. The serum protein electrophoretic pattern and acute phase proteins concentrations in calves with chronic respiratory diseases. Pol. J. Vet. Sci. 16, 385-386. https://doi.org/10.2478/pjvs-2013-0052
Tóthová, Cs., Nagy, O., Seidel, H., Kováč, G., 2012. The effect of chronic respiratory diseases in calves on the serum protein electrophoretic pattern. Acta Vet. Brno. 81, 365-370.
Van Leeuwen, H.J., Heezius, E.C., Dallinga, G.M., 2003. Lipoprotein metabolism in patients with severe sepsis. Crit. Care Med. 31, 1359-1366. https://doi.org/10.1097/01.CCM.0000059724.08290.51.
Volpicelli, G., 2013. Lung sonography. J. Ultrasound Med. 32: 165–171. https://doi.org/10.7863/jum.2013.32.1.165.
Wolfger, B., Schwartzkopf-Genswein, K.S., Barkema, H.W., Pajor, E.A., Levy,

M., Orsel, K., 2015. Feeding behavior as an early predictor of bovine respiratory disease in North American feedlot systems. J. Anim. Sci. 93, 377–385. https://doi.org/10.2527/jas.2013-8030

Wilson, B.K., Richards, C.J., Step, D.L., Krehbiel, C.R., 2017. Best management practices for newly weaned calves for improved health and well-being. J. Anim. Sci. 95, 2170–2182. https://doi.org/10.2527/jas.2016.1006.

Wittum, T.E., Young, C.R., Stanker, L.H., Griffin, D.D., Perino, L.J., Littledike, E.T., 1996. Haptoglobin response to clinical respiratory tract disease in feedlot cattle. Am. J. Vet. Res. 57, 646–649.

Wu, A., Hinds, C.J., Thiemermann, C., 2004. High density lipoproteins in sepsis and septic shock: Metabolism, actions and therapeutic applications. Shock 21, 210-221. https://doi.org/10.1097/01.shk.0000111661.09279.82.

Young, C.R., Wittum, T.E., Stanker, L.H., Perino, L.J., Griffin, D.D., Littledike, E.T., 1996. Serum haptoglobin concentrations in a population of feedlot cattle. Am. J. Vet. Res. 57, 138-141.

Youssef, M.A., El-khodery, S.A., Abdo, M., 2015. A comparative study on selected acute phase proteins (APPs) and immunoglobulins in buffalo and bovine calves with respiratory disease. Comp. Clin. Pathol. 24, 515-520. https://doi.org/10.1007/s00580-014-1933-7.