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REVIEW ARTICLE

Recent Advances in the Management of Foreign Body Syndrome in Cattle and Buffaloes: A Review

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ABSTRACT

Foreign body syndrome (FBS) is a fairly common disease of cattle and buffaloes, especially in the developing countries. This disease is caused by ingestion of indigestible metallic and non-metallic blunt or sharp foreign objects. It is associated with high economic losses and therefore an urgent science-based policy is required to control and manage this syndrome. Indiscriminate feeding habits, feed scarcity, industrialization and mechanization of agriculture are predisposing factors for FBS in bovine and bubaline. The condition is difficult to diagnose solely on the basis of clinical signs and physical examination. However, laboratory diagnosis and imaging techniques like radiography and ultrasonography can be of high diagnostic value in detecting the condition. Anemia, increased packed cell volume, neutrophilia with a left shift, increased total protein, globulin, total bilirubin, Alanine Aminotransferase, Alkaline Phosphatase, Phosphorus and decreased albumin/globulin ratio and Calcium are the common abnormal laboratory findings. Recently, ultrasonography has replaced radiography for diagnosis of FBS in bovine and bubaline due to its availability and accuracy in evaluation of features of the reticulum, detection of penetrating metallic objects, diagnosis and assessment of various sequelae of FBS including; local and diffuse traumatic reticuloperitonitis, reticular, splenic, hepatic, abdominal and thoracic abscesses, diaphragmatic hernia, traumatic pericarditis and pleuropneumonia. Although, FBS is ideally treated with rumenotomy, it can be prevented to a large extent by proper management practices, increasing the awareness among the livestock keepers, oral administration of rumen magnets at the age of one year and reapplication of a new magnet every 4 years in animals at high risk.

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INTRODUCTION

Ingestion of indigestible foreign materials by cattle and buffaloes is a common problem worldwide, known as foreign body syndrome (FBS) (Aref and Abdel-Hakiem, 2013). This syndrome is more common in bovine than in small ruminants because they do not use their lips for prehension and are more likely to eat chopped feed (Misk and Semieka, 2001; Ashfaq *et al*., 2015). Moreover, indiscriminate feeding habits, feed scarcity, industrialization and mechanization of agriculture are predisposing factors for FBS (Semieka, 2010).

The non-metallic foreign body syndrome is a silent killer disease resulting from ingestion of polywastes, rubber, plastics, leather materials, ropes, clothes and cement bags (Reddy and Sasikala, 2012). The presence of foreign bodies in the rumen and reticulum hampers the absorption of volatile fatty acids, consequently leading to reduction in the rate of animal fattening (Igbokwe *et al*., 2003).

When a metallic object such as a wire or nail is swallowed and punctures the reticular wall, the condition is known as "Hardware Disease", "sharp foreign body syndrome" (SFBS) or "traumatic reticuloperitonitis" (TRP). Several complications result from ingestion of indigestible foreign materials such as chellitis, gingivitis, glossitis, stomatitis, pharyngitis, tonsillitis, chock, esophagitis, rumenitis, ruminal impaction, acute or recurrent rumen tympany, localized or diffuse reticuloperitonitis, reticular adhesion and diaphragmatic

hernia. Other consequences include pericarditis, reticular fistulation, reticular, diaphragmatic, mediastinal, hepatic, splenic, lateral and ventral abdominal wall abscesses, vagal indigestion, rupture of left gastro-epiploic artery, traumatic pneumonia and pleurisy (Roth and King, 1991; Floeck and Baumgartner, 2001; Abu-Seida and Al-Abbadi, 2014). These complications depend mainly upon the nature, length and direction of penetration of the swallowed foreign body (Abouelnasr *et al*., 2012).

This condition produces devastating economic losses due to severe reduction in milk and meat production, treatment costs, potential fatalities and fetal losses in affected pregnant animals (Nugusu *et al*., 2013). It may prove lethal because the bacteria and protozoa can contaminate the body cavity resulting in peritonitis and the heart and diaphragm may be punctured by the ingested object, causing their failure (Abu-Seida and Al-Abbadi, 2015).

Due to its high economic importance in dairy animals, FBS is still a matter of concern worldwide, therefore several recent advances in the diagnosis and prevention of the disease have been recorded. This review highlights the recent advances in FBS in cattle and buffaloes.

Incidence: Sharp foreign body syndrome is one of the most common diseases of the digestive tract of cattle and buffaloes. It was recorded in 59.14 and 56.88% of the examined cattle and buffaloes in Pakistan (Khan *et al.*, 1999; Anwar *et al.*, 2013), 23.1% of the examined cattle in Ethiopia (Nugusu *et al*., 2013), 25, 23.38 and 22.9% of the examined buffaloes in Egypt (Aref and Abdel-Hakeim, 2013), India (Ramprabhu *et al.*, 2003) and Iraq (Abu-Seida and Al-Abbadi, 2015), respectively. This high incidence in developing countries is attributed to unsatisfactory animal management and practice of livestock rearing based on hand feeding (Misk *et al.*, 1984). In addition, buffaloes are more prone to FBS than cattle at the same area. Recently calved and senile buffaloes have higher incidence of FBS than dry and lactating buffaloes (Ramprabhu *et al.*, 2003). In addition, dairy cattle are more commonly affected than beef cattle because they are more likely to be fed a chopped feed, such as silage or hay (Kahn, 2005). Moreover, a high incidence of FBS is recorded during drought and harvest season (Sharma and Kumar, 2006).

The mean age of the affected buffaloes is usually 4.0±0.8 years. Moreover, 99.1% of the affected animals are commonly females (Abu-Seida and Al-Abbadi, 2015). In cattle, FBS was recorded in 36.23% of animals ≤3 years old, 33.33% of adult animals (3-7 years old) and 30.43% of old animals (7-11 years of age). In addition, cows are more commonly affected (65.8%) than bulls (37.03%; Anwar *et al.*, 2013).

Indigestible foreign bodies are found either in rumen (58.5%), reticulum (19.3%) or rumen and reticulum (22.2%) of the affected cattle (Anwar *et al.*, 2013). Reportedly, 49.38% of the diseased buffaloes had foreign bodies in the reticulum and only 7.5% had foreign bodies in the rumen. Moreover, the total number of foreign bodies in the reticulum of buffaloes was higher than that in the rumen. Conversely, the total weight of the ruminal foreign bodies was greater than that in the reticulum (Khan *et al*., 1999).

Etiology: The mode of animal prehension, indiscriminate feeding habits, bad nutritional management, heavy industrialization and human habitations are major predisposing factors for the occurrence of such condition in bovine (Khan *et al*., 1999). In addition, pregnancy, tenesmus and vigorous reticular contraction increase the potential for development of SFBS in bovine. Therefore, numerous animals have ruminal and reticular foreign bodies without development of clinical signs and sometimes these foreign bodies pass into feces.

Mostly, the ingested foreign objects are lodged in the reticulum without harm due to their fixation by the honeycomb like reticular cells. The typical foreign body is a metallic object longer than 2.5 cm.

The foreign objects recovered from buffaloes are classified into sharp metallic foreign objects (knives, tin openers, wires, nails, needles and pieces of iron; 75.7%), mixed foreign objects (20.7%), blunt non-metallic objects (sand, stones, gravels, electrical wires, nylon ropes, pieces of clothes, socks, rubber pieces, polyethylene bags and hair balls) (2.1%), blunt metallic foreign objects such as coins (0.9%) and sharp non-metallic foreign objects like bones, feathers and pieces of glass (0.6%; Abu-Seida and Al-Abbadi, 2014; 2015). Sharp foreign bodies, both sharp and blunt foreign bodies or blunt foreign bodies have been recorded in 76.6, 20.7 and 2.7 of the diseased buffaloes, respectively (Abu-Seida and Al-Abbadi, 2015). In cattle, the detected foreign bodies were clothes, plastic, nails, ropes, hair, leather, wires and nails (Tesfaye and Chanie, 2012) (Fig. 1).

Diagnosis: Without an accurate case history and when the victim is admitted after several days of ingestion of a metal object, the diagnosis is more difficult (Ramin *et al*., 2011). Differential diagnosis of SFBS is considered a challenge since the diseased animals show signs similar to those of several other diseases. Uterine or vaginal trauma, metritis, perforating abomasal ulcers, grain overload, ketosis, abomasal displacement, hepatic abscesses, pyelonephritis, intestinal adhesions to the abdominal wall and volvulus, should be considered during the differential diagnosis of SFBS. Thus the diagnosis should be based on case history, clinical symptoms, clinical examination, laboratory diagnosis, electrocardiography, radiography, ultrasonography, necropsy and histopathological diagnosis.

Clinical symptoms: The SFBS is clinically characterized by severe depression, reluctance to move, abduction of fore limbs, progressive weakness (Fig. 2a), sharp drop in milk yield, variable appetite to complete inappetency, mild fever, ruminal stasis, recurrent tympany, scanty hard feces, abdominal pain and death (Singh *et al*., 2008). Sometimes, the diseased buffaloes show systemic reactions, jugular veins engorgement, brisket edema, abnormal lung and heart sounds, respiratory distress and regurgitation of food (Mostafa *et al*., 2015). Rarely localized abscess or fistula at the craniolateral and cranioventral abdomen is recorded (Figs. 2b and c).

Animals with large amount of blunt foreign bodies show anorexia, depression, intermittent respiratory distress, recurrent rumen tympany, rumen stasis, dehydration, reduced milk yield, distended left para lumbar fossa and sometimes vomition (Reddy and Sasikala, 2012; Abu-Seida and Al-Abbadi, 2014).

Clinical signs of traumatic pericarditis (TP) include tachycardia, muffled heart sounds, absence of lung sound in the ventral thorax, asynchronous abnormal heart sounds, distension of the jugular veins and pulsation, submandibular, brisket and ventral abdominal edema (Figs. 2d and e).

Clinical examination: Tympanic sounds are heard on percussion with simultaneous auscultation of paralumbar fossa. By stethoscope, muffled heart beats, reduced gut sounds, and rapid breathing may be heard. Moreover, rectal palpation is a reliable method of diagnosing the rumen impaction in bovine and to exclude uterine or vaginal trauma and metritis (Reddy *et al*., 2014). Electronic metal detector can identify reticular metals but does not distinguish between perforating, non-perforating and non-magnetic foreign bodies (Reddy and Sasikala, 2012).

Briefly, pain tests include pinching of withers, walking on downhill and side stick method. Affected animals will not reflex ventrally when their withers are punched. They may also exhibit pain when a large bar placed under the animal's sternum is forced upwards.

Laboratory diagnosis: Laboratory tests may be helpful in diagnosis of FBS. Hemogram of the diseased animals shows anemia, increased packed cell volume and neutrophilia with a left shift (Reddy *et al*., 2014). Serum biochemical parameters of diseased animals show increased total protein, globulin, total bilirubin, ALT, ALP, P and decreased albumin/globulin ratio and Ca (Ghanem, 2010). Hyperproteinemia is noticed in buffaloes with acute and chronic local TRP, and reticular abscess. Hyper-beta-globulinemia is noticed in animals with chronic local TRP, reticular abscess and purulent pericarditis. Hyper-gamma-globulinemia is evident in animals with acute and chronic local TRP, reticular abscess and purulent pericarditis. Hypoproteinemia associated with severe hypoalbuminemia and very low A/G ratios characterizes animals with acute diffuse TRP, purulent and fibrinous pericarditis (Saleh *et al.*, 2008)

Animals with indigestible plastic materials in the rumen show mild hypocalcemia, hypophosphatemia, hypoglycemia and hypoproteinemia and increase in BUN, and increased values of Methylene Blue Reduction Test (MBRT), total volatile fatty acids and sedimentation activity test (Reddy *et al*., 2014). Severely affected animals may have coagulation abnormalities, as evidenced by prolonged prothrombin time, thrombin time, and activated partial thromboplastin time. Rumen liquor examination reveals a pH of 7.0-8.0 and nil or low protozoal motility and counts (Reddy and Sasikala, 2012).

On hematological examination of animals with TP, erythrocytopenia, pronounced leukocytosis, with shift to left accompanied with neutrophilia, eosinopenia, monocytosis, lymphocytopenia, basopenia and anemia are usual. Hyperfibrinogenemia, hemoconcentration and increased serum AST, ALT, LDH, CPK and bilirubin are also reported. Moreover, cardiac troponin proteins have a value in determining the degree of heart damage (Gunes, 2008).

Pericardiocentesis at the left 4th or 5th intercostal space may be applied under echocardiography to collect a sample of pericardial fluid. However, pneumothorax, fatal arrhythmia, pleuritis and cardiac puncture are potential complications. Protein concentration >3.5 g/dL and WBC count >2500/μL with straw yellow to slightly blood tinged, foamy, and foul smelling pericardial fluid are characteristics of TP (Elhanafy and French, 2012).

Electrocardiography: Electrocardiography (ECG) is one of the most important parameters for an animal suffering from a cardiovascular problem (Reddy *et al*., 2015). Buffaloes should be kept in a standing position in a stock without any sedation (Mousavi *et al.*, 2007). After 30 min rest, 3 channel ECG system and base apex lead was used for obtaining ECG in about 30 sec. For ECG in buffaloes the positive electrode of lead I is attached to the skin of the left 5th intercostal space just caudal to the olecranon process, while the negative electrode is placed on the jugular furrow in the caudal third of the right neck. The ground electrode is placed remote from the heart. To ensure good adherence of electrodes to the skin, shaving and cleaning the skin with alcohol prior to the application of alligator clips and gel should be done (Hasanpour *et al.*, 2008). ECG showed that 70% of normal buffaloes had arrhythmia. Wandering pacemaker (57%), sinus arrhythmia (29%), second degree atrioventicular block (9%) and electrical alternance (5%) were the most common arrhythmias in buffaloes (Mashhadi *et al*., 2014).

Electrocardiography can aid in the diagnosis of TP. Decreased amplitude, electric alternans, slurring, atrial fibrillation are the most common ECG changes in animals with TP (Foss, 1985; Gunes, 2008). Moreover buffaloes with TRP had cardiac arrhythmias (55.6%) including; sinus tachycardia, premature atrial beat, atrioventricular block I and atrioventricular block II (Mousavi *et al.* 2007). ECG is not useful for diagnosis of the early stages of cardiac diseases except for arrhythmias. Meanwhile, the costly echocardiogram is more classical tool for the investigation of the preclinical forms of cardiomyopathies in buffaloes (Reddy *et al.*, 2015).

Radiographic examination: Standing lateral radiographs of the cranioventral abdomen can detect metallic materials in the reticulum but should be taken only after oral administration of a magnet. It is contraindicated to place the affected animal in dorsal recumbency to obtain radiographs, because such position induces stress on adhesions and may lead to diffuse peritonitis.

To determine whether the reticulum is currently perforated, the foreign object must be visible beyond the reticular border (Fig. 3a), unattached to the magnet, or positioned off the floor of the reticulum. Other reliable radiographic findings of penetration include; a depression in the cranioventral aspect of the reticulum, gas accumulation outside the reticulum (Fig. 3b), soft-tissue masses, or a fluid line in the cranial abdomen. Radiography of TRP is 76% sensitive, 93% specific, 85% accurate with 92% positive predictive and 80% negative predictive values (Braun *et al*., 1993).

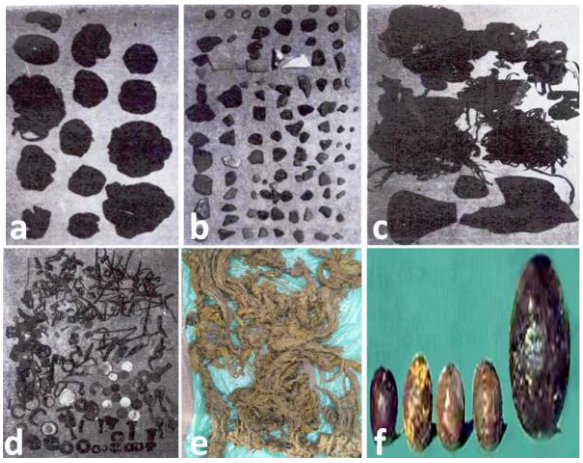

Fig. 1: Compact plastic materials (a), pieces of stone, bones and marbles (b), pieces of rubber and ropes (c), metallic objects (d), pieces of cloths (e) and hair balls (f) recovered from buffaloes. Sources: a, b, c and d: Khan *et al.* (1999), e: Nugusu *et al.* (2013) and f: Abu-Seida and Al-Abbadi (2014).

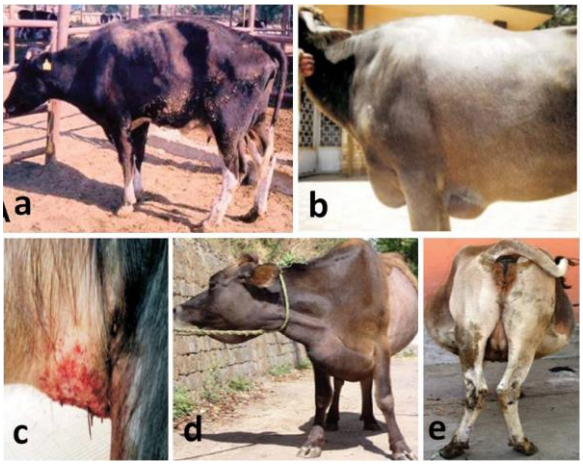

Fig. 2: a) A cow with TRP showing arched back and reluctance to move. b) A buffalo with TRP showing a localized abscess at the left cranioventral abdomen. c) A buffalo with TRP showing a fistula and perforating foreign object at the right cranioventral abdomen. d) A cow with TP showing abduction of fore limbs, jugular venous distention, brisket and submandibular edema and e) A cow with TP showing the classic pear-shaped abdomen. Sources a: Ghanem (2010), b and c: Abdelaal and Floeck (2015) and d and e: Imran *et al.* (2011).

Radiographic examination could be a helpful tool in the diagnosis of diaphragmatic hernia in buffaloes. Intra thoracic circumscribed swelling of soft tissue density representing the reticulum and overlying the caudal border of heart, discontinuation of the diaphragm (Fig. 3c) and sometimes presence of metallic foreign object are the main radiographic findings in diaphragmatic hernia (Aref and Abdel-Hakiem, 2013).

Radiography reveals good thoracic details in early stages of TP, while poor differentiation of thoracic structures is evident at progressive stages. Moreover, gas and fluid accumulation and metallic foreign objects are usually detected in the pericardium and cranial reticulum or caudal thorax (Fig. 3d), respectively. However, it is difficult to distinguish between pleural and pericardial effusion on the basis of radiography (Misk and Semieka, 2001; Masseau *et al*., 2008).

Ultrasonographic examination: Ultrasound has proven a useful diagnostic tool for assessment of different surgical affections in bovine (Abu-Seida, 2012; 2016; Abdelaal *et al*., 2016)**.** The reticulum and surrounding structures are examined by using a 3.5-MHz linear or convex transducer in the area from 6th to 8th intercostal spaces, the transducer is applied to the ventral aspect of the thorax on the left and right of the sternum as well as to the left and right lateral thorax up to the level of elbow (Braun, 2003). The examination is conducted on standing, non-sedated animals for visualization of physiological (Abouelnasr *et al.*, 2014) and pathological conditions of the reticulum in cattle and buffaloes with TRP (Floeck, 2006).

Various sequelae of TRP in both cattle and buffaloes are clarified by ultrasound (Abdelaal *et al*., 2009). The most common ultrasonographic finding in animals with TRP is the corrugation of the reticular wall (Fig. 4a) due to the accumulation of fibrinous deposits interspersed with fluid pockets on the reticular serosa. The thickness of reticular wall, distance between reticulum and abdominal wall and relaxation period are significantly increased in animals with SFBS. Conversely, the reticular motility and amplitude of contraction are significantly decreased. The contraction period shows no significant change.

The ultrasonographic findings vary according to the complications of SFBS (Mostafa *et al*., 2015). Ultrasonographically, the reticular abscesses have an echogenic capsule of varying thickness and surrounded with a homogeneous hypoechogenic to moderately echogenic center (Fig. 4b). The foreign bodies are seen by ultrasonography as hyper echogenic structures penetrating the reticular wall with comet tail artifact (Fig. 4a and b). In certain cases, it is possible to drain abscesses through an ultrasound-guided transcutaneous incision (Braun *et al*., 1998).

Animals with local peritonitis show echogenic strands interspersed with anechoic fluid between the reticulum and/or liver, rumen, spleen (Fig. 4c and d), and abomasum. Animals with diffused peritonitis show diffuse echogenic strands interspersed with anechoic fluid involving the whole abdomen (Fig. 4e). The rumen is displaced 2 to 15 cm from the abdominal wall by hypoechogenic fluid with echogenic fibrin in case of suppurative peritonitis (Braun *et al*., 1998).

Abdominal abscesses of different sizes (2 to 20 cm) appear as anechoic to echogenic center surrounded by echogenic wall. These abscesses usually locate between the reticulum and rumen, abomasum, spleen and/or liver. Meanwhile, thoracic abscesses are usually imaged at 3$^{rd.}$ and 4$^{th.}$ intercostal spaces as circumscribed masses (2 to 20 cm) with echogenic capsule and hypoechoic contents and sometimes they are partitioned by echogenic septa (Mohamed and Oikawa, 2007). Only pulmonary abscesses near the pleura can be imaged by ultrasound (Elhanafy and French, 2012). Other ultrasonographic findings of pulmonary abscess are broadened and hyperechogenic pleura and medium echogenic lungs resembling the liver. Aspiration of the abdominal and thoracic abscesses is minimally invasive and cost-effective technique to obtain an aspirate for confirmation (Tharwat, 2011).

Traumatic pleuropneumonia is a rare complication of hardware disease in buffaloes and ultrasonography played an important role in its diagnosis. Traumatic pleuropneumonia shows hypoechoic exudates in the pleural cavity, absence of reverberation artifacts, presence of comet tail artifacts and hepatized lung (Fig. 4f).

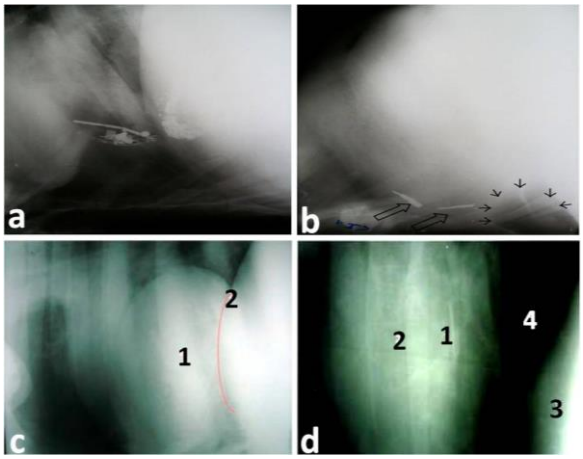

Fig. 3: a) Lateral radiograph of the reticulum showing metallic foreign objects cranial to diaphragm. b) Lateral radiograph of the reticulum showing indistinct diaphragmatic line, intra thoracic metallic densities (hollow arrows) and gas density (black arrows) with embedded metallic object. c) Lateral radiograph of diaphragmatic hernia in a buffalo showing intra thoracic reticulum (1) overlying the caudal border of heart with discontinuation of the diaphragm- drawing red line (2). (d) Lateral radiograph of TP in a buffalo showing radio-opaque metallic foreign object (1) at the caudal border of the heart (2). (3): reticulum and (4): lung. Sources a and b: Athar *et al.* (2010) and c and d: Aref and Abdel-Hakiem (2013).

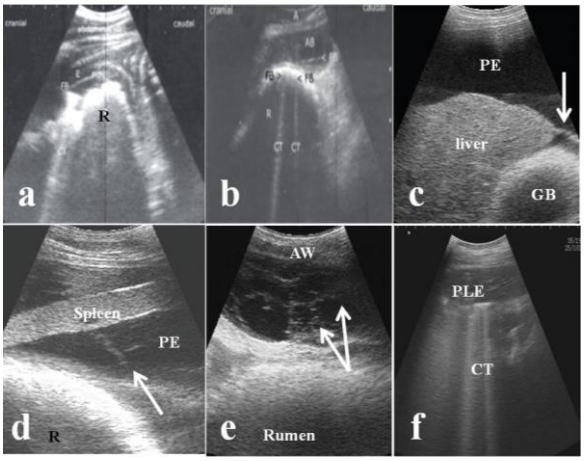

Fig. 4: a) Ultrasonogram of the reticulum (R) of a hardware diseased buffalo showing uneven surface of the reticulum and echogenic foreign body (FB) with a comet tail artifact (CT). F: fibrin; E: exudates. b) Ultrasonogram of the reticulum (R) of a hardware diseased buffalo showing hypoechoic abdominal abscess (AB) and two echogenic foreign objects (FB) with comet tail artifacts (CT). Ultrasonograms of local peritonitis showing corrugated thick reticulum and echogenic fibrin strands (arrows) interspersed with anechoic peritoneal exudates (PE) between the reticulum and liver (c), reticulum and spleen (d) and reticulum and abdominal wall (e). (f) Ultrasonogram of traumatic pleuropneumnia showing hypoechoic exudates in the pleural cavity (PLE), absence of reverberation artifact, presence of echogenic foreign bodies, comet tail artifacts (CT) and hepatized lung. GB: gall bladder, AW: abdominal wall. Sources:. a and b: Abdelaal and Floeck (2015); c, d and e: Imran *et al.* (2011).

Echocardiography is a simple, well-established and rapidly method for assessment of the heart size and function (Hassan and Torad, 2015). It was previously applied in both normal (Torad *et al.*, 2016) and diseased buffaloes (Tharwat and Buczinski, 2011; Hussein and Staufenbiel, 2014)

Echocardiography is the method of choice for confirmation of pericarditis, differentiation between effusive and fibrinous pericarditis, detection of impact of pericardial effusions on the cardiac chambers or function, differentiation between pericardial and pleural effusion and choosing the optimal site of pericardiocentesis (Buczinski, 2009; Athar *et al*., 2012).

Animals with suppurative TP usually have a large amount of hypoechogenic to echogenic pericardial fluid (Fig. 5a). Meanwhile fibrinous TP shows echogenic deposits and strands of fibrin on the epicardium and sometimes in the fluid between the epicardium and pericardium (Fig. 5b). Other ultrasonographic findings include; thick pericardial layer, compressed cardiac ventricles and lungs, medial and dorsal displaced lungs, bright hyperechoic pinpoint echoes representing free gas, vegetations of the tricuspid, mitral and pulmonary valves (Ghanem, 2010), a large hypoechoic area with irregular margins in the cranioventral thorax (Elhanafy and French, 2012) and sometimes obscured heart by the effusion (Schweizer *et al*., 2003). Abdominal ultrasonography in animals with TP reveals reticular changes typical of TRP, hepatomegaly and moderate to severe ascites. Caudal vena cava usually appears dilated and round to oval instead of triangular in cross section. Ultrasonography of the presternal edema reveals excessive accumulation of anechoic fluid separated with echogenic septa.

Reticular diaphragmatic hernias in bovine have been diagnosed by radiography and ultrasonography (Saini *et al*., 2007). However, ultrasonography is still the method of choice for detecting and confirming the diagnosis (Athar *et al*., 2010). Herniated reticulum can be imaged at left 3rd to 5th intercostal spaces beneath the heart or beneath the lung (Abdelaal *et al.*, 2014). Other ultrasonographic findings include; half-moon shaped reticulum, low amplitude contraction and hypoechoic exudates between the reticulum and surrounding thoracic organs (Ramprabhu *et al*., 2003). When the motility patterns of the abdominal and herniated reticulum match, the animal is declared positive for reticular diaphragmatic hernia (Mohindroo *et al*, 2007). Sometimes, thick hyperechoic fibrous bands originate from the herniated mass and extend towards the sternum or the pericardium.

Traumatic suppurative splenitis occurs in 2–14% of cattle with SFBS. Encapsulated masses (3–4 cm diameter) with an echogenic center inside the splenic parenchyma are seen in cattle with traumatic suppurative splenitis (Skarda, 1996).

Ultrasound can assess the stratification of ruminal contents and contraction by moving the probe dorsoventrally either parallel to the last rib or in the left paralumbar fossa from lumbar transverse processes to ventral midline (Imran *et al*., 2011; Braun *et al*., 2013). Therefore, ultrasound can be helpful for diagnosis of foreign bodies inside the rumen.

Laparoscopic examination: Laparoscopy or coelioscopy is a minimally invasive technique that allows the observation of the abdominal organs. It is a promising tool for diagnosis and treatment of several abdominal affections in bovine (Babkine *et al.*, 2006). The application of this technique during abdominal explorations and biopsies avoids the invasive and often useless surgical interferences and even with the diagnosis and prognosis of several abdominal and pelvic conditions (Babkine and Desrochers, 2005).

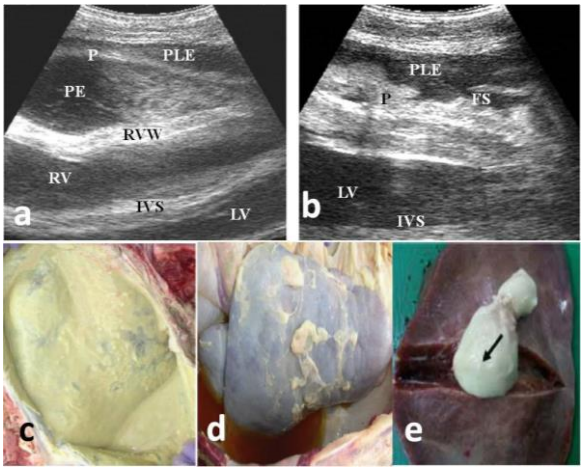

Fig. 5: a) Echocardiogram of a cow with suppurative TP showing anechoic pericadial effusion (PE) with echogenic sediment, pleural effusion (PLE), thickened pericardium (P) and increased right ventricle (RV). RVW; right ventricular wall, IVS: inter ventricular septum, LV: left ventricle. b) Echocardiogram of a cow with fibrinous TP showing pleural effusion (PLE) and thickened pericardium (P) with fibrin shreds (FS). LVW: left ventricular wall, LV: left ventricle, IVS: inter ventricular septum. c) Postmortem photograph of the heart of a cow with suppurative TP. d) Postmortem photograph of the liver of cow with TRP showing hepatomegaly with fibrin shreds on its parietal surface. e) Postmortem photograph of the liver showing traumatic hepatic abscess (arrow). Sources a, b, c and d: Imran *et al.* (2011) and e: Ismail and Abdullah (2014).

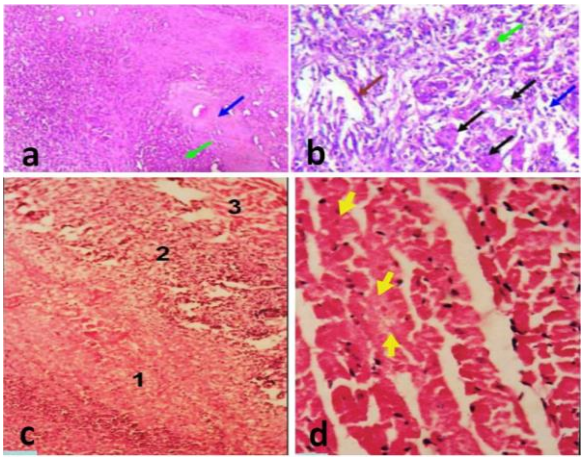

Fig. 6: a) Hepatic abscess showing liquifactive necrosis (blue arrow) and surrounded by a fibrous capsule (yellow arrow) (H & E, 165X). b) Foreign body granuloma showing granulomatous inflammatory exudates infiltrated by giant cell (black arrows) and mononuclear inflammatory cells (yellow and blue arrows) (H & E 450X). c) Heart of a cow with TP showing thickened pericardium (1) and accumulation of fibrinous inflammatory exudates (2) between the pericardium and myocardium (3) (H & E 200X). d) Myocardium of a cow with TP showing atrophy and hyalinosis (yellow arrows) (H & E 400X). Sources: a and b: Ismail and Abdullah (2014); c and d: Ghanem (2010).

Advantages of the laparoscopy include practicality, rapid postoperative recovery and low risk of complications (Rees *et al.,* 2015). On the other hand the main disadvantages are the cost of the instruments and inability to perform laparoscopy in animals with cardiopulmonary diseases and abdominal adhesions (Seeger *et al.*, 2006).

There are three techniques for laparoscopy in bovine including; right and left paralumbar fossa in the standing animals and cranioventral midline laparoscopy with the animal positioned in dorsal recumbency (Anderson *et al.*, 1993; Steiner and Zulauf, 1999). Right flank laparoscopy using a flexible fiberoptic laparoscope, 14 mm diameter and 1120 mm working length, is an easy, rapid and reliable diagnostic aid for TRP (Bakos and Vörös, 2011).

Laparoscopies were performed using a combination of Xylazine and local infiltration anesthesia in standing buffaloes (Ambrose *et al.,* 1993). Before laparoscopic examination, the animals' tail is tied to its hock or neck on the opposite side of the surgery. Both paralumbar fossa are prepared for aseptic surgery then the abdominal wall is infiltrated with 8–10 mL of local anesthetic solution at portal sites. The laparoscopic cannula is inserted in the middle of the fossa, dorsally to the crus of the internal oblique muscle. When cannula is placed in the body wall, the trocar is replaced with a 10-mm rigid, which has an installed video camera and light source, and is connected to the laptop via a USB cable. Tubing connected to the insufflators is attached to the cannula, insufflation is stopped when organs are visualized, and the laparoscope can freely move in the abdomen. In buffaloes with peritonitis, inflammatory signs are visible in the form of congested blood vessel varying degrees of fibrin production and adhesion between abdominal organs and body wall depending upon the stage of peritonitis. Increased peritoneal fluid that changed in color and turbidity and strand of free fibrin in peritoneal fluid are also visible. In few cases heavy adhesion between organ and abdominal wall decreases further exploration of abdominal cavity after laparoscopic examination, the endoscope is removed and CO2 gas/air is released through the open cannula. Then the cannula is removed and the portal sites are closed. Systemic antibiotics and nonsteroidal anti-inflammatory drugs are required for only 24 h after the surgery (Safarchi *et al.*, 2014).

Laparoscopy successfully diagnosed peritonitis of the cranial parts of the abdomen, caused by foreign bodies or laparotomy (Franz *et al.,* 2000), left abomasal displacement (Janowitz, 1998; Tolasi *et al.,* 2015) and occasionally the reticular abscesses in cattle (Wilson and Ferguson, 1984). Moreover, laparoscopy has been used for surgical correction of left displaced abomasum (van Leeuwen *et al.*, 2009; Doga *et al.,* 2010; Sickinger *et al.*, 2013).

In contrary, laparoscopy is not suitable for examination of the ventral abdomen nor for diagnosing non-inflammatory intestinal affections (Franz *et al.,* 2000). Further studies are warranted to evaluate the reliability of laparoscope in diagnosis of SFBS in large animals. Adhesions produced by SFBS may be the main obstacle during laparoscopic examination in bovine.

Necropsy and histopathological examination: Shrunken rumen, strangulated foreign bodies, congested ruminal mucosa and ulceration are the common necropsy findings in animals with FBS. Acute cases of TP show distention of pericardial sac with foul-smelling grayish fluid containing flakes of fibrin and heavy fibrin deposits on the pericardium giving the appearance of "scrambled eggs" (Fig. 5c). In chronic cases, the pericardial sac is grossly thickened and fused with the pericardium by strong fibrinous adhesion with loculi containing pus or straw colored fluid. The causative foreign object can usually be seen (Braun *et al.*, 2007). Sometimes, retrieval of the

foreign body is not possible due to extensive adhesions (Singh *et al*., 2008).

Postmortem findings of SFBS may include; fibrinous adhesions between reticulum and/or diaphragm, spleen, abomasum, rumen, liver (Fig. 5d) and left abdominal wall, large amount of foul-smelling pus containing fibrin clots, adhesions between the intestinal loops and omentum (Chanie and Tesfaye, 2012). Also splenic, pulmonary, reticular, abdominal and hepatic abscesses (Fig. 5e), pleural effusions and foreign bodies can be seen (Sobti *et al*., 1989).

Pathologically, hepatic, pulmonary and splenic abscesses have liquifactive necrosis infiltrated with inflammatory cells mainly, macrophages, neutrophils and lymphocytes and surrounded with fibrous capsule (Fig. 6a). Foreign body granulomas with necrotic center infiltrated by plasma cells, epitheloid cells, macrophages and foreign body giant cells are reported (Fig, 6b). Pathognomonic lesions of TP are thick pericardium, fibrinous network trapping inflammatory cells, atrophy and hyalinosis of myocardium (Figs. 6c and d).

Treatment: Mostly, conservative treatment is indicated in acute cases of SFBS. However, in chronic cases and late pregnant animals, conservative treatment is unsuccessful. Conservative treatments of SFBS include; external massage of the xiphoid process, oral administration of purgative, elevation of the fore limbs, fasting, supportive therapy, intra peritoneal antibiotic injection, and administration of a cage magnet (Horney and Wallace, 1984). However, it is unlikely that the magnet will move into the reticulum due to ruminal stasis**.** Rumen inoculation with 4–8 L of ruminal fluid from a healthy animal is beneficial in animals with prolonged ruminal stasis. If the conservative treatments fail to improve the animal after 3 days, rumenotomy is indicated.

Rumenotomy is a rapid and successful procedure for diagnosis and treatment of FBS. The direct approach to the reticulum through a mid-line incision just posterior to the xiphoid is not preferable due to the possibility of diffuse peritonitis (Dehghani and Ghadrdani, 1995). However, a standing laparotomy is desirable due to the difficult manipulation of such large organ. The site of laparorumenotomy incision, size of the animal, and length of the surgeon's arm should be considered to perform successful rumenotomy (Horney and Wallace, 1984). Moreover, gentle manipulation is recommended to minimize the spreading of infection in animals with traumatic reticulitis. Usually, there is little or no benefit from breaking down chronic adhesion because it tends to reform very rapidly. Also breakdown of recent adhesion is not advised because it may mask and surround an abscess (Weaver *et al*., 2005).

Several techniques for laparorumenotomy including; skin suture fixation, stay suture technique, skin clamp technique, rumenotomy ring, Weingarth's technique and the Gabel rumen retractor (rumen board) have been applied. All techniques are conducted through an approach in the left paralumbar fossa for successful access, exteriorization and securing of the rumen and minimizing contamination. The main difference between these techniques is the method by which the rumen is secured to the abdominal wall or skin (Niehaus, 2008). The stay suture technique is inferior to other techniques due to high incidence of infection while Weingarth's technique is superior to other techniques **(**Dehghani and Ghadrdani, 1995).

In the skin suture fixation technique, the rumen is sutured to the skin using a continuous Connell suture pattern to invert the skin edges under the rumen to minimize contamination. In the stay suture technique, four stay stitches at the cranial, caudal, dorsal and ventral parts of the incision are performed to fix the rumen to the skin. Fixation of the rumen to the skin dorsally and ventrally and fixation of the ruminal incision to the skin incision cranially and caudally are applied by 6-8 towel clamps in the skin clamp technique. An aluminum ring with a rubber ring attached to its inner circumference is used during rumenotomy ring technique to fix the rumen to this rubber ring. In Weingarth's technique, a Weingarth's frame is fixed to the dorsal commissure of the incision by its thumb screw following laparotomy. Then the ruminal incision is fixed to the frame by multiple hooks. The Gabel rumen retractor depends mainly upon a device having a central hole that the rumen is pulled through. The rumen is fixed to the board by a series of bolts (Dehghani and Ghadrdani, 1995). Post-operative complications such as suture abscess, wound dehiscence, subcutaneous emphysema and local peritonitis at the surgical site are recorded (Nugusu *et al*., 2013).

Reticular abscesses may be drained through an ultrasound-guided transcutaneous paracentesis or via rumenotomy into the rumen. Treatment of TP is often unrewarding and usually is addressed toward salvage or short term survival to calving. Diuretics are effective in eliminating the severity of peripheral edema, reducing venous return and preload in animals with pericarditis (Buczinski *et al.,* 2010). Rarely, medical therapy with systemic antibiotics and drainage of pericardial sac permanently cures affected animals.

Following thoracotomy, partial pericardiotomy or pericardiectomy is done in valuable animals. Pericardiotomy involves incising the pericardium, draining the fluid, removal of foreign body if present and thorough irrigation of the pericardial cavity with sterile isotonic saline solution containing antibiotics. An indewelling pericardial drain to allow twice-daily lavage, drainage and instillation of antibiotics may be conducted. Owing to high treatment cost together with poor results and high risk, under normal circumstances, animals with traumatic pericarditis should be humanely and timely euthanized (Ducharme *et al*., 1992).

Prevention: It is difficult to prevent FBS in cattle and buffaloes, however certain precautions have decreased the incidence. These precautions include removal of ferrous and other potentially hazardous objects from field and lane edges, good nourishment and management of the animals, passing of processed foods over magnets to remove metallic objects, avoiding the use of baling wire, completely removing old buildings and fences, keeping animals away from sites of new construction, avoiding the pollution of grazing lands with plastic bags, hair, hoof, wool and avoiding the unsupervised grazing of animals (Nugusu *et al.,* 2013; Reddy *et al*., 2014). Moreover, administration of reticular magnets at the age of 1.5-2

years has become a popular preventive measure for hardware disease (Weaver *et al*., 2005). After oral administration, most magnets drop firstly into the rumen then move to the reticulum by ruminoreticular contractions. Metallic foreign bodies are attracted and fixed to the magnets, and consequently do not penetrate the reticulum as easily as when they are free. The extensive prophylactic use of these has reduced the incidence of TRP by 90-98% in cattle and 89-91% in buffaloes. A time dependent increase in the proportion of buffaloes developing TRP is noticed after 4 years of magnet administration, not due to loss of magnetic power but due to fixation of numerous foreign objects on the magnet. Therefore, reapplication of a second new magnet is recommended after four years of the first one particularly in animals at high risk (Al-Abbadi *et al*., 2014).

Conclusions: Foreign body syndrome of cattle and buffaloes is still a challenge in veterinary field all over the world particularly in developing countries. Although the condition has no specific clinical signs, it has several hematological, biochemical and radiographic characteristics. Moreover, ultrasonography provides recent advances in diagnosis and prognosis of this syndrome.

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