REVIEW ARTICLE

APPLICATIONS OF ULTRASONOGRAPHY FOR DIAGNOSIS OF DISEASES AND DISORDERS IN DAIRY BUFFALOES

Jezie A. Acorda[1]

ABSTRACT

Ultrasonography has been widely used in domestic animals for reproductive management and for diagnosis of diseases and disorders. In dairy buffaloes, although extensive studies have been conducted on pregnancy diagnosis and fetal monitoring for reproductive management, there are very few reports on the use of diagnostic ultrasound for disease diagnosis. Most of the studies in this species involved diagnosis of diseases and disorders of the lungs, diaphragm, heart, reticulum, omasum, rumen, intestines, liver, uterus, ovaries, mammary gland and teats. Very few investigations have been done on the musculo-skeletal system, the spleen, urinary tract, sensory organs and male reproductive organs. In addition, Doppler echocardiography has not been utilized for diagnosis of cardiovascular disorders. Further investigations on the use of ultrasonography for diagnosis of various diseases and disorders of the buffalo are warranted.

Key words: buffalo, dairy, disease, disorder, ultrasonography

INTRODUCTION

Diagnostic ultrasound or ultrasonography is an imaging procedure that utilizes high-frequency waves to send pulses into the body and reconstructs the returning pulses to form cross-sectional images of organs, tissues and blood flow (Manion, 2006; Mattoon and Nyland, 2015). Unlike radiography which produces static images, ultrasonography provides both anatomical and physiological information, since the images are produced in real-time. Thus, both structure and function of the organ can be visualized and evaluated. In addition, ultrasonography produces an image that is just a thin slice of the organ or tissue showing the internal architecture of the organ, unlike radiography which displays the external appearance of the whole structure or organ (Kealy *et al.*, 2011).

Images produced by diagnostic ultrasound are displayed in four modes: A-mode or amplitude mode, B-mode or brightness mode, M-mode or motion mode and Doppler mode. A-mode shows the intensity of echoes through variation of the amplitude of the spike. This is used mostly for eye examination. B-mode can be displayed as a two-dimensional (2-D), three-dimensional (3-D) or four-dimensional mode (4-D) real-time image of the structure.

[1]Department of Veterinary Clinical Sciences, College of Veterinary Medicine, University of the Philippines Los Baños, Laguna, Philippines (email: jaacorda@up.edu.ph).

Four-dimenisional mode is basically a real-time 3-D Mode. The position of the echoes corresponds to the depth at which the echoes originate the information (Kealy *et al.*, 2011; Mattoon and Nyland, 2015). M-mode traces the motion of the structures against time and is used for cardiac evaluation. Doppler ultrasonography shows the flow and velocity of the blood. Pulsed wave Doppler emits a short pulse of sound at a specific frequency, continuous wave Doppler emits and receives echoes simultaneously, color flow Doppler uses color maps of blood flow while triplex Doppler combines B-mode and color and spectral Doppler information (Kealy *et al.*, 2011; Mattoon and Nyland, 2015).

Ultrasound frequencies used in ultrasound range from 2-15 MHz, lower frequencies are used to image deep structures while high frequencies are used to visualize superficial structures (Kealy *et al.*, 2011). There are different scanners used in ultrasonography. Sector scanner produces a triangular field of view, linear scanner produces a rectangular field, while the curvilinear array is linear arrays shaped into convex curves. They can have a large or small radius (microconvex) (Mattoon and Nyland, 2015).

Although the use of ultrasonography for pregnancy diagnosis and monitoring of the fetus has been thoroughly investigated in dairy buffaloes, limited studies have been conducted on the use of diagnostic ultrasound for diseases and disorders in this animal. In contrast with other ruminants, there are few reports on ultrasonographic findings in normal and diseased organs in dairy buffaloes. Recent studies in dairy buffaloes focused on gastro-intestinal disorders (traumatic reticuloperitonitis, omasal impaction, intestinal obstruction), respiratory disorders (diaphragmatic hernia, lung consolidation, pleural effusion, pulmonary emphysema, bronchopneumonia, pleuritis), cardiac disorders (traumatic pericarditis, endocarditis), abdominal (hepatic and abdominal abscesses), mastitis and urolithiasis (Abu-Seida, 2016).

LUNGS, PLEURA AND DIAPHRAGM

Ultrasound examination

The lungs and the pleura can be visualized at both sides of the thorax between the 3rd and 11th intercostal spaces using a 3.5-5 MHz convex scanner. The pleural leaves appear as broad, smooth, hyperechoic lines between the lung surface and the thoracic wall, moving synchronously with respiration. The presence of air limits the evaluation of the parenchyma of the lungs. In normal lung, numerous reverberation artifacts running regularly and parallel to the pleura are seen (Abu-Seida, 2016). The echotexture of the nonventilated lung is similar to that of the liver (Tharwat and Oikawa, 2011).

Respiratory disorders

Respiratory disorders that can be visualized using thoracic ultrasonography include thoracic abscess, pleural effusion, pleuritis, pleuropneumonia, pulmonary emphysema, bronchopneumonia and lung consolidation. Pulmonary emphysema is characterized by the presence of numerous comet-tail artifacts appearing as bright, closely situated echogenic bands running perpendicular to the pleura in the lung tissue from the lung surface. In bronchopneumonia, scattered round and wedge-shaped hypoechoic zones are seen on the surface of the lungs accompanied by comet-tail artifacts. Weak, defined and blurry reverberation artifacts are seen in severe pneumonia with lung consolidation (Tharwat and Oikawa, 2011).

Lung abscess can only be diagnosed by ultrasonography when it is located near the pleura. In lung abscess, the pleura appears broad and hyperechoic while the lung tissue is hypoechoic, like the hepatic parenchyma. When the lung parenchyma is compressed, well-defined abscesses could be visualized as round to ovoid anechoic areas with thin reflective capsules. In pleuritis and pleural effusion, hypoechoic fluid with hyperechoic bands are seen in the pleural cavity (Tharwat and Oikawa, 2011).

Mohamed and Oikawa (2007) reported the presence of thoracic abscesses of various sizes (5-15 cm in diameter) in the left third and fourth intercostal spaces appearing either echogenic or anechoic with or without echogenic septae partition. Ultrasonography has also been used in the diagnosis of lung cysts caused by echonococcosis (Kumar *et al.*, 2016).

Diaphragm

The diaphragm separates the abdominal and thoracic cavities and appears ultrasonographically as a thin echogenic line. Diaphragmatic hernia is easily evaluated and diagnosed using ultrasonography (Mohindroo *et al.*, 2007; Athar *et al.*, 2010b) through: a) the presence of reticulum, seen as a thick echogenic structure in the thoracic cavity; b) observance of reticular motility at the level of 4th and 5th intercostal spaces (Kumar and Saini, 2011; Abdelaal *et al.*, 2014a); c) biphasic contractions (Kumar and Saini, 2011), monophasic with reduced contraction frequency or absence of reticular contraction; d) imaging of the herniated reticulum beneath the lung or heart; and e) the presence of hypoechoic inflammatory adhesion between the reticulum and thoracic organs (Abdelaal *et al.*, 2014a).

HEART

Ultrasound examination

The heart can be examined ultrasonographically in standing buffaloes using a 3.5 or 2-4 MHz convex scanner or 5.0 MHz microconvex scanner (Kumar *et al.*, 2012) from the 3rd-4th intercostal spaces (Acorda and Pilapil, 2008), 4th-5th intercostal spaces (Kumar *et al.*, 2012; Abu-Seida, 2016) or 3rd to 6th intercostal spaces (El-Khodery *et al.*, 2010) in both sides of the thorax. To assess spatial relationships of the different cardiac structures, B-mode can be used while measurements of cardiac dimensions and evaluation of valve, camber and septal movements can be evaluated using M-mode (Abu-Seida, 2016). Doppler ultrasonography can be used to determine blood flow; however, no known studies on Doppler ultrasonography of cardiac structures have been conducted.

In non-pregnant adult normal buffaloes, using the left and right sides of the thorax, cardiac structures such as the right and left ventricles and ventricular outflow can be imaged; however, the pulmonary artery was poorly visualized. During diastole and systole, left ventricular dimensions were greater than those of the right ventricle, and the size of both ventricles was significantly greater during diastole than systole. Both interventricular septum and left ventricular free wall dimensions were greater in systole than in diastole (El-Khodery *et al.*, 2010). Tricuspid, mitral and pulmonary valves can also be imaged using ultrasonography (Mohamed, 2010). In the study of Acorda and Pilapil (2008), the heart appeared more visible on the left than on the right side of the thorax.

Constante *et al.* (2017) investigated the relationship between echocardiographic features and milk production in buffaloes and observed greater diameter of the aorta in high milk-producing buffaloes than in low milk producing ones and higher left ventricular internal diameter at diastole, left ventricular diastolic volume and stroke volume in non-pregnant high milk-producing buffaloes than in pregnant ones.

Cardiac disorders

In endocarditis, hyperechoic valves with nodular or proliferative vegetative lesions are seen. Tricuspid valves are the most commonly affected, followed by mitral and pulmonary valves (Hussein and Staufenbiel, 2014). Ultrasonograms of congestive heart failure in buffaloes show the accumulation of massive anechoic fluids in the pericardial sacs, peritoneum and pleura, representing effusions in the three structures (Mohamed, 2010; Hussein and Staufenbiel, 2014). In pericarditis, the pericardial effusions were seen in both the right and left sides of the heart and appear as anechoic to hypoechoic with or without fibrin deposition in the pericardial sac or uniform echogenic texture suggestive of pus (Kumar *et al.*, 2012). In traumatic pericarditis, uniform echogenic pus or anechoic to hypoechoic areas with echogenic fibrin thread interspersed in between the pericardial sac are seen (Mohamed, 2010; Kumar *et al.*, 2012; Attia, 2016).

GASTROINTESTINAL TRACT

Ultrasound examination

Evaluation of the gastrointestinal tract in buffaloes is relatively challenging because of the large size and mobility of the organs and the presence of large amounts of air. A 3.5 or 5.0 MHz convex or microconvex scanner is sufficient for transcutaneous ultrasonography of the gastrointestinal tract in standing animals (Buczinski, 2008; Mohindroo *et al.*, 2008; Abouelnasr *et al.*, 2014; Abu-Seida, 2016). In Egyptian buffaloes, the rumen, reticulum, omasum, abomasum, small intestine and large intestine could be visualized (Khalphallah *et al.*, 2016d).

The reticulum can be imaged at the 6th to 8th intercostal spaces (Abu-Seida, 2016) at the ventral aspect of the thorax on both sides of the sternum and up to the level of the elbow on both sides of the thorax (Mostafa *et al.*, 2015). Abouelnasr *et al.* (2014) observed that the reticulum can be best accessed from the left and right ventral thorax than from the midline. The normal reticulum appears as a half-moon-shaped or crescent-shaped structure with a smooth contour and the mucosal folds visualized as irregular echogenic projections extending into the lumen (Abouelnasr *et al.*, 2014; Mostafa *et al.*, 2015). Most buffaloes had biphasic reticular contractions while a few exhibit triphasic contraction with 4-5 contractions in four minutes. Because of the presence of air, the different layers of the normal reticular wall cannot be visualized (Abouelnasr *et al.*, 2014). Normal reticular parameters in buffaloes include: a) frequency of reticular contraction (4.95±0.15 per 5 mins); b) reticular wall thickness (0.45±0.07 cm); c) distance between reticulum and abdominal wall (2.08±0.06 cm); d) duration of 1st, 2nd and total reticular contractions (2.00±0.12, 3.90±0.22 and 5.90±0.25 sec, respectively); e) relaxation period of reticulum (60±1.8 sec); and f) amplitude of 1st and 2nd reticular contractions (5.46±0.32 and 17.67±0.32 cm, respectively) (Mostafa *et al*., 2015).

The normal omasum can be seen at the 8th to 9th intercostal spaces. It is seen as a round or oval structure with thick hyperechoic wall and echogenic leaves, the movement of the latter can be seen in real-time B-mode. Contraction of the omasum causes changes in the distance between its wall and the scanner, appearing as large and close to the scanner at the start of the contraction and very small and away from the scanner as contraction progresses (Mohindroo *et al.*, 2008).

Gastrointestinal disorders

Disorders of the gastrointestinal tract which can be imaged using ultrasonography include traumatic reticuloperitonis, ruminal and omasal impaction, intussusception and foreign body syndrome.

Among the different gastrointestinal disorders, traumatic reticuloperitonitis has been thoroughly investigated. Ultrasonography can be used for early diagnosis of traumatic reticuloperitonitis because it provides accurate information on the various sequelae of the disease such as acute local peritonitis, chronic local peritonitis, acute diffuse peritonitis, reticular, thoracic and abdominal abscesses, traumatic pericarditis, pleuropneumonia and diaphragmatic hernia (Abdelaal *et al.*, 2009; Mostafa *et al.*, 2015). Moreover, it assists in determining the exact location and extent of the lesions (Abdelaal *et al.*, 2009). Acute local peritonitis shows a half-moon shaped reticulum with slight loss of its shape and contour with inflammatory deposits on the serosal surface and is characterized by reduced frequency of biphasic reticular contractions and increase reticular wall thickness (Mohamed and Oikawa, 2007; Abouelnasr *et al.*, 2012; Mostafa *et al.*, 2015; Khalphallah *et al.*, 2016b). Chronic local peritonitis, on the other hand, has a corrugated reticulum with loss of its normal shape, echogenic strands interspersed with anechoic material (Mostafa *et al.*, 2015) and reticulophrenic adhesions (Athar *et al.*, 2010b). In diffuse peritonitis, anechoic fluid without hyperechoic margins with floating fibrious shreds are seen (Athar *et al.*, 2010b). The ingested metallic foreign bodies are imaged by ultrasound as hyperechoic structures with comet tail artifact or with acoustic shadow in hardware diseased buffaloes. Perforations of the soft tissues by foreign bodies cause inflammation and abscess formation (Abdelaal and Floeck, 2015).

Ultrasonography has also been found to be an ideal diagnostic tool for investigating esophageal obstruction in buffaloes (Tiwari *et al.*, 2011). Ruminal impaction is characterized by reduced rumen motility with 0.83 contraction per two minutes which was lower than the normal value of 3.0 contractions per two minutes, rumen and reticular atony and no reticular motility (Athar *et al.*, 2010c). Impacted omasum is characterized by absence of motility, no visible omasal leaves with a prominent distal acoustic shadow seen at the right side of the abdomen (Mohindroo *et al.*, 2008).

In intussusception, the following are observed through ultrasonography: swollen invaginated intestinal wall appearing hyperechoic in cross-section, "sandwich" configuration of the affected intestine observed in longitudinal view, increased intestinal diameter, decreased intestinal motility, anechoic intestinal contents and accumulation of hypoechogenic fluid between the dilated intestinal loops (Tharwat, 2011). Mechanical obstruction caused by duodenal intussusception is seen as two concentric rings with outer echogenic wall and hypoechoic lumen (Khalphallah *et al.*, 2016c).

Recently, ultrasonography has replaced radiography for diagnosis of foreign body syndrome in buffaloes due to its availability and accuracy in evaluation of the ultrasound features of the reticulum, detection of penetrating metallic objects and assessment of various sequelae including acute local reticuloperitonitis, chronic local reticuloperitonitis, acute diffuse reticuloperitonitis, reticular, splenic, hepatic, abdominal and thoracic abscesses, diaphragmatic hernia, traumatic pericarditis and pleuropneumonia (Esawy *et al.*, 2015;

Abu-Seida and Al-Abbadi, 2016). In foreign body syndrome, ultrasonography was found to be effective in assessing fibrinous deposits (Aref and Abdel-Hakiem, 2013).

LIVER

Ultrasound examination

The liver can be examined by diagnostic ultrasound using a 3.5 MHz convex scanner through the 9th-12th intercostal spaces (Acorda and Alejandro, 2007) or 11th intercostal space (Khalphallah *et al.*, 2016a) of the right flank of the buffalo. The hepatic parenchyma showed uniform hypoechoic appearance evenly distributed throughout the entire organ. Vascular structures appeared as circular or irregularly rounded anechoic structures, the portal veins having hyperechoic walls while hepatic veins had hypoechoic walls. The gall bladder appeared as an anechoic structure with echogenic walls adjacent to the hepatic parenchyma between the 11th and 12th intercostal spaces in the middle of the right flank of the animal (Acorda and Alejandro, 2007). Khalphallah *et al.* (2016a) were not able to visualize the gall bladder from the right 12th intercostal space (Khalphallah *et al.*, 2016a).

In the investigation by Constante and Acorda (2012a) on the ultrasonographic features of the liver in lactating Bulgarian Murrah buffaloes at different stages of lactation, they observed that the echo mean values of the liver parenchyma were lowest in the late stage of lactation compared to the early and middle stages. Hepatic and gall bladder wall thickness and gall bladder lumen diameter showed no differences among the different stages of lactation.

Hepatic disorders

Hepatic ultrasonography has been used for diagnosis of hepatic lipidosis, abscesses, fascioliasis and liver cysts in buffaloes. Ultrasonograms of hepatic lipidosis had either increased or decreased hepatic echogenicity with unclear liver boundaries (Tharwat, 2012a). Moderate and severe increases in echogenicity of the hepatic parenchyma were observed in moderate and severe fatty liver, respectively (Hussein *et al.*, 2014). Buffaloes with patent *Fasciola* spp. infection showed hyperechoic heterogeneous liver parenchyma with multiple echogenic foci, thicker hyperechoic gall bladder wall, distended gall bladder with homogeneous anechoic lumen (Tharwat 2012b; Robles *et al.*, 2017), bile duct mineralization and edema of the gallbladder wall (Tharwat, 2012b). Hepatic abscess appears as hypoechoic to echogenic circumscribed mass, from pinpoint to 10 cm in diameter, with or without hyperechoic wall. They can be located intrahepatic or peri-hepatic, between the liver and reticulum (Abdelaal *et al.*, 2014b). Liver cysts caused by echinococcosis can also be imaged using diagnostic ultrasound (Kumar *et al.*, 2016).

SPLEEN

The spleen in buffaloes can be imaged ultrasonographically using a 3.5 MHz convex scanner in the dorsal aspect of the left flank in the region of the 10th to 12th intercostal spaces. Khalphallah *et al.* (2016d) obtained images of the spleen of Egyptian buffaloes at the distal part of the left 6th and 7th intercostal spaces between the caudal points of scapula and elbow. The splenic capsule appears as hyperechoic, the parenchyma as homogenously hypoechoic (Acorda *et al.*, 2009; Khalphallah *et al.*, 2016d) and the splenic vessels as anechoic with hyperechoic walls (Acorda *et al.*, 2009).

A comparison of the ultrasonographic features of the spleen at different stages of lactation showed that the echo mean values of the spleen parenchyma were lowest in late stage of lactation (Constante and Acorda, 2012a).

URINARY ORGANS

Ultrasound examination

In buffaloes, the right kidney can be imaged by the transcutaneous technique using a 3.5-5.0 MHz convex scanner while the left kidney and urinary bladder can be visualized utilizing the transrectal technique with a 6-8 MHz linear scanner (Saharan *et al.*, 2013). Constante and Acorda (2012a) compared the ultrasound features of the kidney of Bulgarian Murrah buffaloes at different stages of lactation: a) early (1-3 months, 12 animals), b) middle (4-6 months, 11 animals); and c) late (7-9 months, 10 animals) and observed no differences in the thickness at different stages of lactation.

Urinary disorders

In buffalo calves, ultrasonography was found to be a helpful tool in diagnosis of urine retention with and without urinary bladder rupture, nephrolithiasis, hydronephrosis and urethrolithiasis (Abdelaal *et al.*, 2016). In ruptured urethra, the urethral calculi can be seen as hyperechoic masses with acoustic shadowing and the site of urethral rupture is visualized as disruption in the continuity of the urethral lumen with distant anechoic area. In addition, the prepuce, scrotum and inguinal areas show diffuse anechoic areas separated by hyperechoic fibrin threads (Abu-Seida, 2012). Uroperitoneum with either ruptured or intact urinary bladder is seen as anechoic areas in the abdomen with hyperechoic floating internal organs (Tharwat and El-Deeb, 2015). Renal and urethral calculi are seen as hyperechogenic dots with acoustic shadowing (Abdelaal *et al.*, 2016).

FEMALE REPRODUCTIVE ORGANS

Ultrasound examination

The ovaries and uterus can be imaged transrectally in buffaloes using a 5.0-8.0 MHz linear scanner. Constante and Acorda (2012a) investigated the ultrasonographic appearance, measurements and echo mean values of the ovaries and uterus of buffaloes at various physiological states. In all stages, the ovaries were seen as non-homogenous hypoechoic ovoid structures with anechoic follicles. Ovarian mean measurements in animals in estrus were higher than in pregnant and non-pregnant animals. In non-pregnant and pregnant animals, the uterus was visualized as a thick hyperechoic band with a homogenously hypoechoic lumen. Animals in estrus had thinner left horn wall than non-pregnant and pregnant animals. The echo mean values of the ovaries and uterus of animals in estrus were lower than non-pregnant and pregnant buffaloes.

The udder can be examined directly through the transcutaneous technique utilizing a 3.5-5.0 MHz linear, sector or convex scanner (Rambadu *et al.*, 2008; Fasulkov, 2012). The udder can also be examined using gel application and standoff methods (Thomas *et al.*, 2004). Examination of the teat is most commonly conducted through the water bath technique a 7.5 MHz linear scanner (Rambadu *et al.*, 2008; Fasulkov, 2012). In the water bath method, the mammary gland is cleaned with antiseptic solution then dipped in a polyethylene bag filled with water and the scanner is applied on the outer wall of the polyethylene bag (Thomas *et al.*, 2004). Rambadu *et al.* (2008) observed gel application and water bath methods produced clearer ultrasound images than direct contact and stand-off methods. In the study by Constante and Acorda (2012b) on the ultrasound features of the udder and teat of water buffaloes at different stages of lactation, they observed that teat wall was thicker in early stage of lactation compared to the late phase and echogenicity of the udder wall, udder parenchyma and teat wall decreases with increasing days of lactation.

Uterine and ovarian disorders

Uterine abnormalities such as abscesses, adhesions, tumors, hydrometra, mucometra, pyometra and abnormal uterine fluids can be diagnosed through ultrasonography. Pyometra is characterized by distended uterus with echogenic uterine fluid (Ali *et al.*, 2009). Ultrasound can also be used to determine the type of intrauterine fluid, purulence or mucous, detect a small amount of fluid in subclinical metritis and identify origin of vaginal discharges due to metritis or vaginitis. Color Doppler sonography of the middle uterine artery has been utilized in determining the duration and degree of uterine torsion (Hussein, 2013). Ovarian and uterine pathologies not detectable by rectal palpation can be visualized through diagnostic ultrasound (Medana and Abdel-Aty, 2010). Ultrasonography has also been used to detect silent ovulation and anestrus (Rahman *et al.*, 2012) and early embryonic death in buffaloes (Naikoo *et al.*, 2009).

Udder and teat disorders

Ultrasonographic appearance of subclinical mastitis includes irregular contour of teat canal and sinus, overlapped papillary duct and rosette of Furstenberg, loss of the three-layered appearance of the affected teat wall and clear visualization of udder parenchyma and gland sinus. In clinical mastitis, ultrasound examination revealed loss of the three-layered appearance of the teat wall, complete obstruction of teat canal, thickened teat wall, disappearance of rosette of Furstenberg, irregular teat cistern filled with homogenous hypoechoic milk and anechoic milk alveoli filled with hypoechoic fluid (Kotb *et al.*, 2014). Buffaloes with parenchymatous abscesses reveal complete obstruction of the teat canal and cistern with hyperechoic materials, multiple abscesses filled with hypoechoic or hyperechoic caseated pus and surrounded by hyperechoic thick capsules (Kotb *et al.*, 2014). Other disorders that can be visualized through ultrasonography include udder lesions such as mammitis, varicosity, edema, abscess, haematoma, atrophy and fibrosis and teat lesions including thelitis, intraluminal foreign bodies, intraluminal obstructions, teat stenosis, trauma/fistula, fibrosis and atresia (Rambadu *et al.*, 2009).

MALE REPRODUCTIVE ORGANS

Ultrasonography of the testicles can assist the veterinarian in the diagnosis of various infertility disorders (Abu-Seida *et al.*, 2015). However, there are very few studies on the use of ultrasound in buffalo bulls. Ultrasonography has been used to image ruptured urethra with scrotal swelling, malignant sertoli cell neoplasm, hydrocele, testicular hypoplasia and scrotal hernia in buffalo bulls (Abu-Seida, 2012).

In a study by El-Khawaga *et al.* (2012) on the effect of different doses of GnRH analogue on the bull's reproductive organs, they observed that the diameter of the testicle and width of epididymal tail did not differ significantly before and after treatment, the heights of the ampulla ductus deferens and seminal vesicle differed before and after treatments, the prostatic body differed after treatments, the pars disseminate of the prostate gland and the height of the bulbourethral gland did not differ regardless of the dose of treatment.

MISCELLANEOUS ORGANS

Eyes

Ocular ultrasonographic examination in buffaloes can be conducted using the transpalpebral approach, through the skin of the upper eyelid, using either a 6-8 MHz (Assadnassab and Fartashvand, 2013) or 10 MHz linear scanner in both horizontal and vertical imaging planes with the animal restrained without the use of sedation, analgesia or anesthesia (Abu-Seida, 2016). The different structures of the eye appear similar to those of other domestic animals ultrasonographically (Assadnassab and Fartashvand, 2013). Both the aqueous humour and vitreous body are seen as anechoic areas, while the anterior and posterior lens capsule, iris and cornea are visualized as hyperechoic structures. With advancing age, ocular measurements such as axial length, depth of vitreous chamber and thickness of the cornea, lens and scleroretinal rim increase (Kassab, 2012).

Ligaments

The patellar ligaments can be seen as highly echogenic structures, the medial patellar ligament is seen as a round structure, the middle patellar ligament as thick and triangular while the lateral patellar ligament as flattened triangular structure in cross-section. Desmotomy of the patellar ligament tends to increase the thickness and width of the ligaments (Kassab and Badawy, 2011).

Integument

Superficial swellings in the head, neck, chest wall, abdominal wall, limbs, gluteal region, perineal region and udder of buffalo can be examined precisely, non-invasively and rapidly using ultrasound to diagnose for presence of abscess, hematoma, hernia, bursitis, urethral diverticula and tumor (Abouelnas *et al.*, 2016).

Body condition score

The precision of body condition score (BCS) established for buffaloes was confirmed through ultrasonographic measurement of body fat reserves. The BCS with a scale of 1-5 which utilized skeletal checkpoints, identified through anatomy and fat reserves, adequately reflected the actual fat reserves as revealed by ultrasonography (Alapati *et al.*, 2010; Anitha *et al.*, 2011; Kapa and Alapati, 2013).

CONCLUSION

Extensive studies have been conducted in some diseases and disorders of the buffalo, including traumatic reticuloperitonits, traumatic reticulitis, lung disorders, diaphragmatic hernia, endocarditis, subclinical and clinical mastitis and various teat disorders. However, very few studies have been conducted on other organs such as the liver, spleen, kidneys, eyes, male reproductive organs and musculo-skeletal system. Furthermore, Doppler ultrasonography has not been utilized for diagnosis of cardiovascular disorders. There is a need, therefore, to conduct ultrasonographic examination of other organs in dairy buffaloes for diagnosis of diseases and disorders.

REFERENCES

Abdelaal AM, Floeck M, El Maghawry S and Baumgartner W. 2009. Clinical and ultrasonographic differences between cattle and buffaloes with various sequelae of traumatic reticuloperitonitis. *Veterinarni Medicina* 54:399-406.

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

Abdelaal A, Gouda S, Ismail A and Gomaa M. 2014a. Reticular diaphragmatic hernia in Egyptian buffaloes: Clinical, hemato-biochemical and ultrasonographic findings. *Pak Vet J* 34:541-544.

Abdelaal AM, Gouda SM and Tharwat M. 2014b. Clinico-biochemical, ultrasonographic and pathological findings of hepatic abscess in feedlot cattle and buffaloes. *Vet World* 7(5):306-310.

Abdelaal AM, Al-Abbadi OS and Abu-Seida AM. 2016. Transcutaneous and transrectal ultrasonography in buffalo calves with urine retention. *Asian J Anim Vet Adv* 11(2): 79-88.

Abouelnas K, El-Shafaey ES, Mosbah E and El-Khodery S. 2016. Utility of ultrasonography for diagnosis of superficial swellings in buffalo (*Bubalus bubalis*). *J Vet Med Sci* 78(8):1303-1309.

Abouelnasr KS, Mosbah E, Karrouf GI and Zaghloul AE. 2012. Comparative ultrasonographic findings of traumatic reticulitis, perireticular abscess and diaphragmatic hernia in buffalo (*Bubalus bubalis*). *J Am Sci* 8(8):590-595.

Abouelnasr KS, Mosbah EM, Karrouf GI and Zaghloul AE. 2014. Ultrasonography of normal reticulum in 30 healthy buffalo (*Bubalus bubalis*). *J Appl Anim Re*s 42:153-159.

Abu-Seida AMA. 2012. Ultrasonographic diagnosis of some scrotal swellings in bulls. *Pak Vet J* 32:378-381.

Abu-Seida, AM, Ahmed KA, Torad FA and Marouf SA, 2015. Ultrasonographic and histopathological findings in rams with epididymo-orchitis caused by *Brucella melitensis*. *Pak Vet J* 35:456-460.

Abu-Seida AM. 2016. Current status and prospect of ultrasonographic application in buffaloes. *Asian J Anim Vet Advances* 11(2):44-157

Abu-Seida AM and Al-Abbadi OS. 2014. Recurrent rumen tympany caused by trichobezoars in buffaloes (*Bubalus bubalis*): A series report. *Thai J Vet Med* 44:147-151.

Abu-Seida AM and Al-Abbadi OS. 2016. Recent advances in the management of foreign body syndrome in cattle and buffaloes: A review. *Pak Vet J* 36(4):385-393.

Acorda JA and Alejandro VB. 2007. Ultrasonographic features of the liver and associated structures in female water buffaloes (*Bubalus bubalis*). *Philipp J Vet Med* 44 (2): 85-90.

Acorda JA, Ancheta MN, Detera MAJ, Cabrera LA and Maligaya RL. 2009. Comparative ultrasound features and echo histograms of the spleen in female goats (*Capra hircus*), sheep (*Ovis aries*) and buffaloes (*Bubalus bubalis*). *Philipp J Vet Anim Sci* 35(2): 135-146.

Acorda JA and Pilapil FMIR. 2008. B-mode and M-mode ultrasonography of the heart in female buffaloes (*Bubalus bubalis*) in the Philippines. *Philipp J Vet Med* 45(1): 7-13.

Alapati A, Kapa SR, Jeepalyam S, Rangappa SMP and Yemireddy KR. 2010. Development of the body condition score system in Murrah buffaloes: Validation through ultrasonic assessment of body fat reserves. *J Vet Sci* 11(1):1-8.

Ali A, Abdel-Razek AK, Derar R, Abdel-Rheem HA and Shehata SH. 2009. Forms of reproductive disorders in cattle and buffaloes in Middle Egypt. *Reprod Dom Anim* 44:580-586.

Anitha A, Rao KS, Suresh J, Moorthy PRS and Redy YK. 2011. A body condition score (BCS) system in Murrah buffaloes. *Buffalo Bull* 30(1):79-99.

Aref NM and Abdel-Hakiem MAH. 2013. Clinical and diagnostic methods for evaluation of sharp foreign body syndrome in buffaloes. *Vet World* 6(9):586-591.

Assadnassab G and Fartashvand M. 2013. Ultrasonographic evaluation of buffalo eyes. *Turk J Vet Anim Sci* 37:395-398.

Athar H, Mohindroo J, Singh K, Kumar A and Raghunath M. 2010a. Comparison of radiography and ultrasonography for diagnosis of diaphragmatic hernia in bovines. *Asian J Anim Vet Adv* 11(2):144-157.

Athar H, Mohindroo J, Singh K, Kumar A and Randhawa S. 2010b. Clinical, haemato biochemical, radiographic and ultrasonographic features of traumatic reticuloperitonitis in bovines. *Indian J Anim Sci* 80(7):608-612.

Athar H, Mohindroo J, Singh K and Singh T. 2010c. Clinical, Heamatobiochemical, radiographic and ultrasonographic findings in bovines with rumen impaction. *Intas Polivet* 11(2):180-183.

Attia NE. 2016. Cardiac biomarkers and ultrasonography as tools in prediction and diagnosis of traumatic pericarditis in Egyptian buffaloes. *Vet World* 9(9):976-982.

Buczinski S. 2008. Omasal ultrasonography in cows and buffaloes. *Vet Radiol Ultrasound* 49:495-496.

Constante JL and Acorda JA. 2012a. Ultrasound features of the spleen, liver and kidney of Bulgarian Murrah buffaloes (*Bubalus bubalis* L.) at different stages of lactation. *Philipp J Vet Anim Sci* 38(1):73-84.

Constante JL and Acorda JA. 2012b. Ultrasound features of the udder and teat of water buffaloes (*Bubalus bubalis* L.) at different stages of lactation. *Philipp J Vet Med* 49(2):76-82.

Constante JL, Acorda JA, Tandang AG and Pajas AMGA. 2017. B-Mode and M-mode Ultrasonography of the heart of lactating dairy water buffaloes (*Bubalus bubalis* L.). *Philipp J Vet Med* 54(1):1-8.

El-Khawaga ARM, Kandiel MMM, Sosa GA, El-Roos MEAA, Abdel-Ghaffar AA and El-Azab AESI. 2012. Ultrasound imaging of the testes and accessory sex glands in buffalo bulls treated with gonadotrophic releasing hormone. *J Reprod Infertility* 3(1):08-16.

El-Khodery SA, Nassif MN and Hassan HY. 2010. Two dimension echocardiography in normal buffaloes (*Bubalus bubalis*). *J Appl Anim Res* 37(1):57-61.

Esawy EEE, Badawy AM and Ismail SF. 2015. Ultrasonographic diagnosis and clinical evaluation of the foreign body complications in the compound stomach of cattle and buffaloes. *J Advanced Vet Res* 5(3):109-120.

Fasulkov IR. 2012. Ultrasonography of the mammary gland in ruminants: A review. *Bulg J Vet Med* 15(1):1-12.

Hussein HA. 2013. Validation of color doppler ultrasonography for evaluating the uterine blood flow and perfusion during late normal pregnancy and uterine torsion in buffaloes. *Theriogenology* 79:1045-1053.

Hussein HA, El-sheikh KR, Deheidy NS and Tharwat M. 2014. Diagnostic investigations for fatty liver syndrome in Egyptian buffaloes. *Global Vet* 12(5):682-686.

Hussein HA and Staufenbiel R. 2014. Clinical presentation and ultrasonographic findings in buffaloes with congestive heart failure. *Turk J Vet Anim Sci* 38:534-545.

Kapa SR and Alapati A. 2013. Body condition score (BCS) system in Murrah buffaloes. *Buffalo Bull* 32(Special Issue 2):1290-1298.

Kassab A. 2012. Ultrasonographic and macroscopic anatomy of the enucleated eyes of the buffalo (*Bos bubalis*) and the one-humped camel (*Camelus dromedarius*) of different ages. *Anatomia Histologia Embryologia* 41:7-11.

Kassab A and Badawy A. 2011. Ultrasonographic anatomy of the patellar ligaments before and after medial patellar desmotomy in buffaloes (*Bos bubalis*). *Emir J Food Agric* 23(5):460-465.

Kealy JK, McAllister H and Graham JP. 2011. Diagnostic Radiology and Ultrasonography of the Dog and Cat. 5th ed. St. Louis, Missouri: Saunders Elsevier.

Khalphallah A, Abdelhakiem M and Elmligy E. 2016a. The ultrasonographic findings of the liver, gall bladder and their related vasculatures in healthy Egyptian buffaloes (*Bubalus bubalis*). *Assiut Vet Med J* 62(149):156-162 .

Khalphallah A, Abu-Seida AM, Abdelhakiem M, Elmeligy E and Mahmoud UT. 2016b. Laboratory, radiographic and ultrasonographic findings of acute traumatic reticuloperitonitis in buffaloes (*Bubalus bubalis*). *Asian J Anim Vet Advances* 11(11):675-683.

Khalphallah A, Aref NEM, Elmeligy E and El-Hawari SF. 2016c. Clinical and ultrasonographic observations of functional and mechanical intestinal obstruction in buffaloes (*Bubalus bubalis*). *Vet World* 9(5):475-480.

Khalphallah A, Elsayed HK, Elmeligy E and El-Hawari SF. 2016d. The ultrasonographic findings of the gastrointestinal tract and spleen in healthy Egyptian buffaloes (*Bubalus bubalis*). *Assiut Vet Med J* 62(148):9-47.

Kotb EE, Abu-Seida AM and Fadel MS. 2014. The correlation between ultrasonographic and laboratory findings of mastitis in buffaloes (*Bubalus bubalis*). *Global Vet* 13: 68-74.

Kumar A and Saini NS. 2011. Reliability of ultrasonography at the fifth intercostal space in the diagnosis of reticular diaphragmatic hernia. *Vet Record* 169: 391b.

Kumar A, Saini NS, Mohindroo J and Sood NK. 2012. Ultrasonographic features of normal heart and liver in relation to diagnose pericarditis in bovine. *Indian J Anim Sci* 82: 1489-1494.

Kumar A, Saini NS, Mohindroos J, Singh BB, Sangwan V and Sood NK. 2016. Comparison of radiography and ultrasonography in the detection of lung and liver cysts in cattle and buffaloes. *Vet World* 9(10):1113-1120.

Mannion P. 2006. Diagnostic Ultrasound in Small Animal Practice. Oxford: Blackwell Publishing Company.

Mattoon JS and Nyland TG. 2015. Small Animal Diagnostic Ultrasound. 3rd ed. St. Louis, Missouri: Saunders Elsevier.

Medana MS and Abdel-Aty AM. 2010. Advances in ultrasonography and its applications in domestic ruminants and other farm animals reproduction. *J Advanced Res* 1:123-128.

Mohamed T and Oikawa S. 2007. Ultrasonographic characteristics of abdominal and thoracic abscesses in cattle and buffaloes. *J Vet Med Ser A* 54:512-517.

Mohamed T. 2010. Clinicopathological and ultrasonographic findings in 40 water buffaloes (*Bubalus bubalis*) with traumatic pericarditis. *Vet Record* 167:819-824.

Mohindroo J, Kumar M, Kumar A and Singh SS. 2007. Ultrasonographic diagnosis of reticular diaphragmatic hernias in buffaloes. *Vet Record* 161:757-758.

Mohindroo J, Kumar A, Sangwan V, Udehiya R and Singh SS. 2008. Ultrasonographic evaluation of the omasum in cows and buffaloes. *Vet Radiol Ultrasound* 49:295-299.

Mostafa MB, Abu-Seida AM, Abdelaal AM, Al-Abbadi OS and Abbas SF. 2015. Ultrasonographic features of the reticulum in normal and hardware diseased buffaloes. *Res Opin Anim Vet Sci* 5:165-171.

Naikoo M, Patel DM, Derashri HJ, Lekshmi P, Vala KB, Khade N and Mehraj UDD. 2009. Ultrasonographic evaluation of early embryonic death (EED) in Mehsani buffaloes. *Vet World* 2(7):283.

Rahman MS, Shohag AS, Kamal MM, Parveen N and Shamsuddin M. 2012. Application of ultrasonography to investigate postpartum anestrus in water buffaloes. *Reprod Dev Biol* 36(2):103-108.

Rambadu K, Sreenu M, Kumar RVS and Rao TSC 2008. Ultrasonography of the udder and teat in buffaloes: A comparison of four methods. *Buffalo Bull* 27:269-273.

Rambadu K, Sreenu M, Kumar RVS and Rao TSC. 2009. Ultrasonography of the udder and teat in buffaloes. *Buffalo Bull* 28(1):6-10.

Robles JH, Divina BP, Acorda JA and Saludes TA. 2017. Ultrasonographic features of the liver and gall bladder of water buffaloes with patent *Fasciola* spp. infection. *Philipp J Vet Anim Sci* 42(1):92-100.

Saharan S, Singh P, Sahu R, Chawla SK and Chandolia RK. 2013. Ultrasonographic studies on obstructive urolithiasis in male buffalo calves. *Indian J Vet Surg* 34:51-53.

Tharwat M. 2011. Diagnostic ultrasonography in cattle and buffaloes with intestinal obstruction. *J Agric Vet Sci* 4:67-80.

Tharwat M. 2012a. Ultrasonography as a diagnostic and prognostic approach in cattle and buffaloes with fatty infiltration of the liver. *Polish J Vet Sci* 15(1):83-93.

Tharwat M. 2012b. Ultrasonographic findings in cattle and buffaloes with chronic hepatic fascioliosis. *Trop Anim Health Prod* 44:1555-1560.

Tharwat M and El-Deeb W. 2015. Clinical, biochemical and ultrasonographic findings in buffalo calves with obstructive urolithiasis. *Global Vet* 14:118-123.

Tharwat M and Oikawa S. 2011. Ultrasonographic evaluation of cattle and buffaloes with respiratory disorders. *Trop Anim Health Prod* 43:803-810.

Thomas CS, Svennersten-Sjaunja K, Bhosrekar MR and Bruckmaier RM. 2004. Mammary cisternal size, cisternal milk and milk ejection in Murrah buffaloes. *J Dairy Res* 71: 162-168.

Tiwari DK, Dar MUD, Jhala SK, Pitroda A, Joy N, Patil DB, Parikh PV, Prajapati BG and Badgujar CL. 2011. Ultrasonography and computerized radiography aided diagnosis of oesophageal foreign body obstruction and its treatment in a buffalo. *Buffalo Bull* 30(2):107-110.