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REVIEW

Internal Medicine

Ultrasonography of the liver in healthy and diseased camels (*Camelus dromedaries*)

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ABSTRACT. In camels, hepatic diseases are relatively common and most of them are misdiagnosed as a cause of illness because signs may be subtle. In addition, diagnostic laboratory methods are insufficient as hepatic enzymes can also be elevated in camels with cardiac or skeletal muscle damage. Examples of liver diseases in camels are hepatic lipidosis, hepatitis, cirrhosis, hepatic necrosis, choleostasis, hyperplasia of biliary epithelium, hydatid cysts, glycogen deposition, cholangitis, cholangiohepatitis, calcified hydatid cyst and hepatic abscesses. When the liver is examined by ultrasonography, the clinician gets sufficient information about the size, position, echopatterns of the hepatic parenchyma, bile ducts and outlines of the hepatic blood vessels. Ultrasonography has been used previously in camels only for reproductive purposes. However, during the past decade, it has been used for scanning of the healthy organs as well as evaluation and determining the diagnosis and prognosis of non-reproductive disorders. Examples of diseases evaluated by ultrasonography in camels are paratuberculosis, trypanosomiasis, abdominal and urinary disorders, thoracic diseases, renal tumors, pyelonephritis, renal abscessation, gastrointestinal tumors, chronic peritonitis and splenic abscessation. Ultrasound-guidance in biopsy of hepatic lesions and in portocentesis has also been reported in camels. This mini review article is written to shed light on ultrasonography of the liver and its blood vessels in healthy camels as well as finding in camels with hepatic disorders such as fatty infiltration of the liver, hepatic abscesses and calcification of the bile ducts.

KEY WORDS: camel, dromedary, imaging, liver, ultrasonography

In camels, hepatic diseases are relatively common [2, 8, 10]. In an abattoir-based study carried out in Egypt on 44 livers with hepatic disorders, lesions included hepatic lipidosis (47.7%), hepatitis and cirrhosis (27.2%), hepatic necrosis (18.1%), and choleostasis and hyperplasia of biliary epithelium (6.8%) [13]. Another large-scale, abattoir-based study conducted in Iran on the prevalence of hepatic lesions in dromedary camels showed that out of 150 examined livers, 40 had hepatic lesions (26.7%). These lesions included hydatid cysts (65%), cirrhosis (10%), hepatic lipidosis (12.5%), glycogen deposition (2.5%), cholangitis (2.8%), cholangiohepatitis (5%), calcified hydatid cyst (2.5%), hepatic abscess (2.5%), and lipofuscin pigments (17.5%) [9].

In bovines, ultrasonography has been described as a useful tool for the diagnosis of many hepatic disorders [1, 4, 5, 7, 16, 17]. During the last 10 years, ultrasonography has been used for scanning of the lungs and pleura [19], echocardiography of the normal camel heart [22], ultrasonography of the gastrointestinal viscera [23] and hepatic and renal imaging [24]. Ultrasound-guidance in biopsy of hepatic and renal specimens [29] and in portocentesis [28] has also been reported in camels. In diseased camels, diagnostic ultrasonography has been applied for the evaluation and determining the prognosis of camels with abdominal distension [25], paratuberculosis [27], trypanosomiasis [18], abdominal disorders [30], urinary disorders [31], thoracic diseases [32], renal tumors [26], pyelonephritis [37, 38], renal abscessation [37], gastrointestinal tumors [33], chronic peritonitis [20] and splenic abscessation [21].

In camels, numerous liver diseases are not diagnosed ante-mortem and may be overlooked on many occasions because the signs are vague or nonspecific. In addition, hematology and serum biochemistry may be unhelpful, and therefore ancillary tests may be required. This mini review article is written to shed light on ultrasonography of the liver and its blood vessels and normal findings in healthy camels as well as finding in camels with some hepatic disorders.

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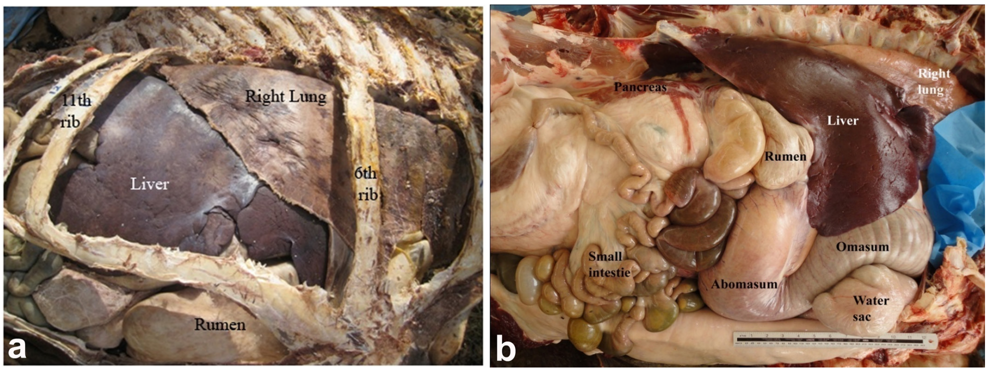

Fig. 1. Anatomical position of the liver in a camel, right side view. The liver is positioned in a camel carcass preserved in 10% formalin solution (a) and at postmortem examination without preservation (b).

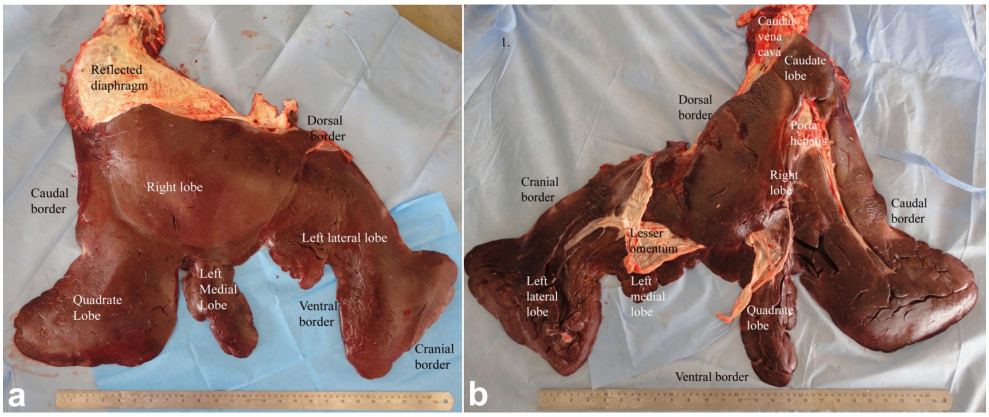

Fig. 2. Lobulation of the liver in an adult camel (a, parietal surface; b, visceral surface).

ANATOMY OF THE LIVER IN CAMELS

The camel liver lies on the right side of the midline, under cover of the ribs. It extends from the 5th to 12th rib. The camel liver has two surfaces, diaphragmatic (parietal) surface, and visceral surface (Fig. 1). In the fresh state, the camel liver is dark brown. It contains a high amount of interlobular connective tissues leading to a firmer consistency than in other domesticated animals. Its weight in the adult camels varies from 6.0–10.0 kg [15]. The liver is composed of right, left and quadrate lobes. Hepatic lobulation in camels is distinct and each lobule is surrounded by connective tissue. The gallbladder is absent and the two hepatic ducts unite to form the common hepatic duct before opening into the duodenum. The absence of the gallbladder as a landmark between the quadrate and right lobes poses some difficulty in determining the boundary between these lobes [15]. The left lobe is subdivided into left medial and left lateral lobes (Fig. 2).

ULTRASONOGRAPHIC EXAMINATION OF THE LIVER IN CAMELS AND NORMAL FINDINGS

For preparation of hepatic ultrasonography, the right side (5th intercostal space (ICS)–right flank) of the abdomen should be clipped and the skin is shaved. If necessary, the camel should be slightly sedated using an intravenous xylazine injection (0.02 mg/kg). Ultrasonographic examination is usually carried out in camels using a 3.5 MHz sector or linear transducer. After the application of transmission gel to the transducer, the liver is examined, beginning at the right paralumbar fossa and extending forward to the 5th ICS. Initially, the hepatic texture, hepatic and portal veins, and visceral and diaphragmatic surfaces are examined. The position of the dorsal and ventral liver margins, the caudal vena cava and the portal vein are measured in relation to the dorsal midline. Measurements of distance from the dorsal midline are taken afterwards using ultrasound to identify the pertinent inner points [24].

EVALUATION OF THE HEPATIC ECHOTEXTURE, SIZE AND POSITION

The parenchymal pattern of the normal camel liver consists of numerous medium echoes uniformly distributed over the entire liver. The portal and hepatic veins are seen within the normal texture and the lumens of these vessels appear anechoic [24]. The

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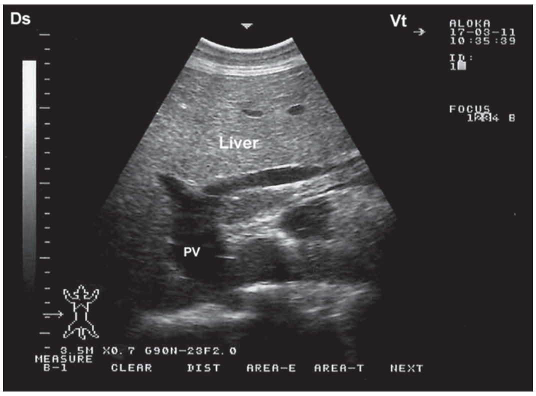

Fig. 3. Ultrasonogram of the hepatic parenchyma and portal vein (PV) in a healthy camel. The vein is positively differentiated from the hepatic vein in the area of the portal fissure because the portal veins in this region are characterized by stellate ramifications. This image is taken at the right 10th intercostal space. Ds, dorsal; Vt, ventral.

Table 1. Dimensions (means ± SD) of the hepatic parenchyma, caudal vena cava and portal vein obtained at the 5th through 11th right intercostal spaces in 22 healthy camels as estimated by ultrasound

	Intercostal space						
	11th	10th	9th	8th	7th	6th	5th
Liver							
Distance of proximal margin to midline	39.1 ± 7.4	44.9 ± 8.2	50.8 ± 7.5	56.0 ± 6.3	61.1 ± 4.4	64.9 ± 6.4	67.0 ± 2.0
Distance of ventral margin to midline	50.0 ± 6.8	59.9 ± 8.0	68.9 ± 6.9	73.7 ± 6.2	75.1 ± 4.3	75.4 ± 5.1	76.5 ± 3.5
Size	13.6 ± 4.0	14.1 ± 4.3	16.5 ± 6.3	12.9 ± 4.6	13.2 ± 3.3	10.2 ± 3.7	9.5 ± 3.5
Caudal vena cava							
Distance from hepatic capsule	9.9 ± 1.9	9.9 ± 2.5					
Distance from body surface	11.6 ± 1.6	12.9 ± 2.3					
Diameter	3.1 ± 0.5	3.8 ± 0.4					
Portal vein							
Distance from hepatic capsule	9.3 ± 1.7	7.8 ± 2.2	8.2 ± 2.4				
Distance from body surface	9.9 ± 2.6	9.2 ± 2.5	10.0 ± 1.6				
Diameter	3.3 ± 0.5	3.3 ± 0.6	3.8 ± 0.9				

All measurements are taken in centimeters [15].

portal veins are positively differentiated from the hepatic veins in the area of the portal fissure because the portal veins in this region are characterized by stellate ramifications (Fig. 3). The distances between the dorsal midline and the proximal and distal liver margins from the 11th to 5th ICSs are shown in Table 1. The proximal margin of the liver is positioned parallel to the border of the lungs in a cranioventral to caudodorsal direction. The distance between the proximal liver margin and the dorsal midline is the shortest (39.1 ± 7.4 cm) at the 11th ICS and increases cranially to the 5th ICS. Similarly, the distance between the ventral liver margin and the dorsal midline is shortest (50.0 ± 6.8 cm) at the 11th ICS and increases cranially to the 5th ICS. The size of the liver is largest at the 9th ICS and smallest at the 5th ICS (Table 1) [24].

EVALUATION OF THE HEPATIC BLOOD VESSELS

The depth of the caudal vena cava and portal vein from the body surface and hepatic capsule and the diameter of these vessels at the different ICSs are also summarized in Table 1 [24]. The caudal vena cava is consistently situated dorsally and medially to the portal vein. The caudal vena cava is imaged triangular (Fig. 4). In camels, the caudal vena cava is visible at the 11th and 10th ICSs and its distance from the hepatic capsule to the body surface is similar at both locations. The diameter of the caudal vena cava is largest at the 10th ICS (3.8 ± 0.4 cm) [24]. The portal vein is imaged at the 11th, 10th and 9th ICSs and is round on a cross-sectional view. Its distance from the hepatic capsule is largest at the 11th ICS and smallest at the 10th ICS. The size of the portal vein is largest at the 9th ICS and is smaller, but similar, at the 11th and 10th ICSs. Compared to the echogenic wall of the portal vein (Fig. 3), the hepatic vein's wall appears to be hypoechoic to anechoic (Fig. 5).

ULTRASOUND-GUIDED HEPATIC BIOPSY IN CAMELS

Biopsy procedures are as follows: firstly, the right side of the abdomen and thorax should be clipped and skin shaved. The shaved abdominal area is then sterilized using standard surgical disinfection techniques. To obtain adequate restraint, the camel is sedated with xylazine (0.07 mg/kg BW), and the region chosen for collecting hepatic biopsy is infiltrated with 10 m*l* of 2% lidocaine hydrochloride [29].

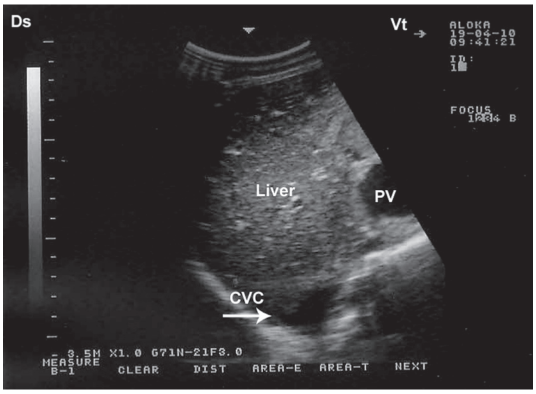

Fig. 4. Ultrasonogram of the caudal vena cava (CVC) in a healthy camel. In this animal, the imaged vein was triangular (arrow). The image was taken from right 11th intercostal space. Ds, dorsal; Vt, ventral.

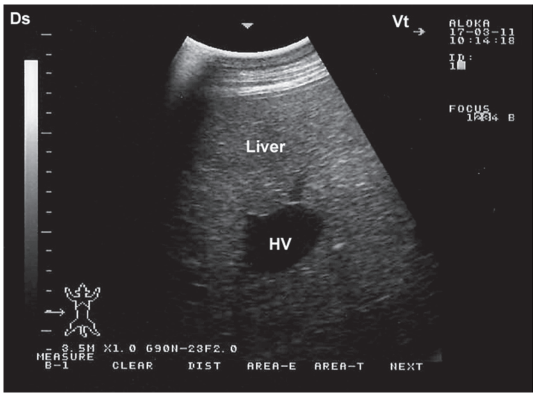

Fig. 5. Ultrasonogram of the hepatic vein (HV) in a healthy camel. The vein wall appeared to be anechoic. The image was taken from right 9th intercostal space. 1 =hepatic parenchyma. Ds, dorsal; Vt, ventral.

Fig. 6. A free-hand, ultrasound-guided advancement of the biopsy needle towards the hepatic parenchyma.

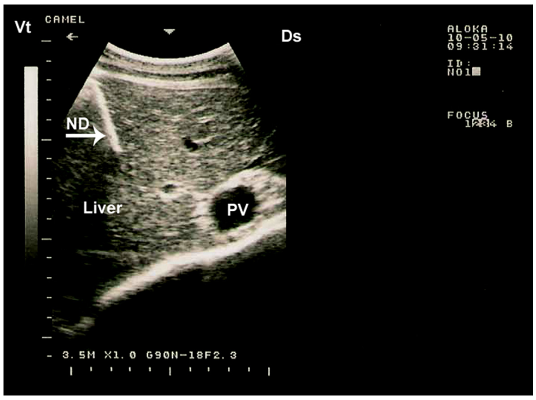

Fig. 7. Hepatic biopsy in a camel. The needle is clearly visible within the hepatic parenchyma. PV, portal vein; ND, needle; Ds, dorsal; Vt, ventral.

After application of a generous amount of alcohol to the skin, imaging of the liver is performed with a 3.5 MHz sector transducer. The liver is firstly scanned to determine the optimal biopsy site. After the application of transmission gel to the transducer, the liver is examined beginning at the right paralumbar fossa and extending forward to the 5th ICS. Prior to biopsy, and under aseptic conditions, a small incision is made in the skin over the suggested biopsy site with the point of a scalpel blade. Using a free-hand technique, a 14G×150 mm spinal biopsy needle is used (Fig. 6). The biopsy needle is then advanced through the skin incision, and then under real-time ultrasound guidance towards the hepatic parenchyma. When the needle is considered to be in the correct position, the plain stylet is withdrawn and the notched part is inserted and advanced 1 cm into the hepatic tissue. The needle can always be identified on the ultrasound within the hepatic parenchyma (Fig. 7) while the specimen is being obtained [29]. Both the needle and the forked stylet are then removed with the sample of hepatic tissue (Fig. 8).

PORTOCENTESIS

Hepatic portal blood has been the subject of a variety of physiological and/or nutritional studies in cattle. Portocentesis is either performed via catheterization of the vein during laparotomy or through an ultrasound-guided approach. Real-time ultrasound-guided portocentesis can be performed in camels. The procedure is also safe and accurate in the hands of trained and experienced personnel [6, 11, 28, 34, 36, 39]. To restrain the camel in a sitting position, xylazine is administered intravenously (0.07 mg/kg BW). The right side of the thorax and abdomen is clipped and shaved and ultrasonographic examination is performed using a 3.5 MHz transducer. After the application of transmission gel, the liver is examined beginning from the right paralumbar fossa caudal to the last rib and moving stepwise cranially to the 5th ICS. Visualizing the portal vein a site for portocentesis is identified and the region is infiltrated with 10 m*l* of 2% lidocaine. A stab incision is made through the skin with the tip of a scalpel blade. A spinal needle (14G×200 mm) is then advanced through the skin incision into the hepatic parenchyma towards the portal vein using an ultrasound-guided, free-hand

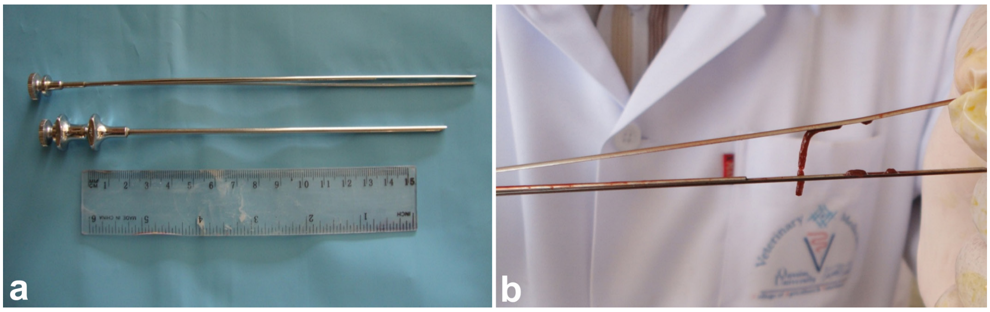

Fig. 8. Liver biopsy in camels. A 14G × 150 mm spinal biopsy needle can be used for liver biopsy in camels (a). Image (b) shows a hepatic biopsy specimen from a camel.

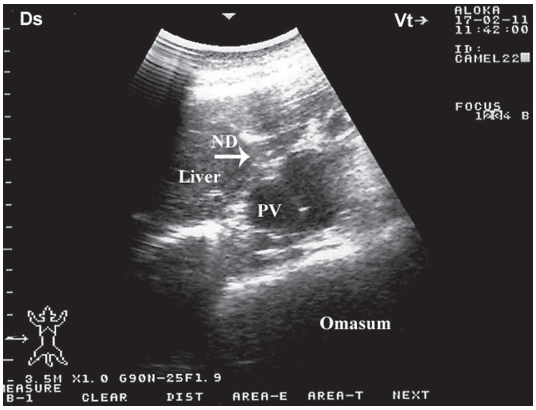

Fig. 9. Portocentesis in a healthy camel. The needle (ND) appears on the screen as a sharp bright line. The image was taken in the right 10th intercostal space using a 3.5 MHz convex transducer. PV, portal vein; Ds, dorsal; Vt, ventral.

technique. To reach the portal vein, the needle is directed parallel to the horizontal plane of the ultrasound probe and between 20–40° to the vertical plane of the transducer. The needle appears on the ultrasound image as a fine echogenic line (Fig. 9). When the tip of the needle has entered the portal vein the stylet is removed and blood is withdrawn using a 10-m*l* plastic syringe [28].

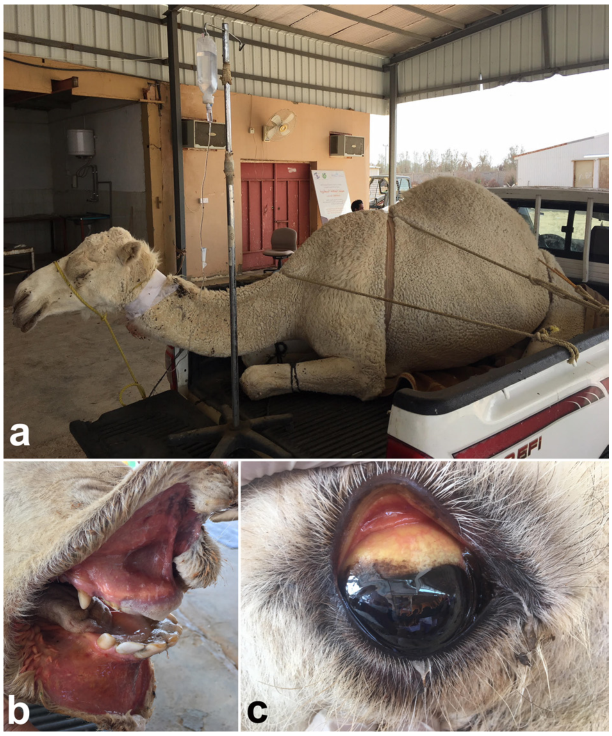

Fig. 10. Profound depression in a female camel with fatty infiltration of the liver (a). Yellowish discoloration of the oral mucosa (b) and sclera (c) are shown. Diagnosis was confirmed histologically.

HEPATIC DISORDERS

Fatty infiltration of the liver

Fatty liver or hepatic lipidosis is a major metabolic disease of farm animals and is associated with decreased health status and reproductive performance. The condition is not a specific disease but rather the end result of one or more of the metabolic processes [12, 14]. Hepatic lipidosis is characterized by increased mobilization of depot fat, decreased rate of oxidation of mobilized fat, increased formation of fat and reduced rate of removal from the liver. More severe injury results in necrosis. The condition has no characteristic clinical signs and even icterus is not a sign of uncomplicated cases. In advanced cases, profound depression with yellowish discoloration of the mucus membranes can be detected (Fig. 10).

Ultrasonographically, the hepatic parenchyma appears echogenic on ultrasonograms compared to normal hepatic parenchyma (Fig. 11). The condition may be focal or diffuse [35]. In severe cases, the echoes weaken as the distance from the abdominal wall increases because the fat-containing hepatocytes enhance acoustic impedance [17]. Consequently, the region near the abdominal wall is hyperechoic, whereas areas that are more distant are hypoechoic or cannot be imaged at all (Fig. 12).

Liver abscesses

In camels, liver abscesses are the most common liver lesions found at slaughter. They are detected only at the time of slaughter because camels seldom exhibit any clinical signs. In a study carried out at Nyala abattoirs, South Darfur State, Sudan during a period from 2009 to 2011, out of 822 slaughtered camels, 111 had liver abscesses (13.5%); 90 (81.1%) were less than seven years old and

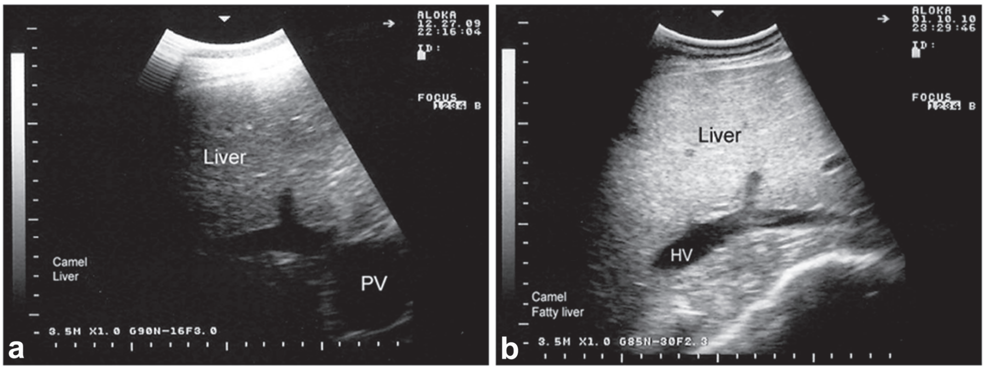

Fig. 11. Ultrasonograms of fatty infiltration of the liver in a camel (b) compared to healthy one (a). The liver appears hyperechogenic on ultrasonograms compared to normal imaging picture. PV, portal vein; HV, hepatic vein.

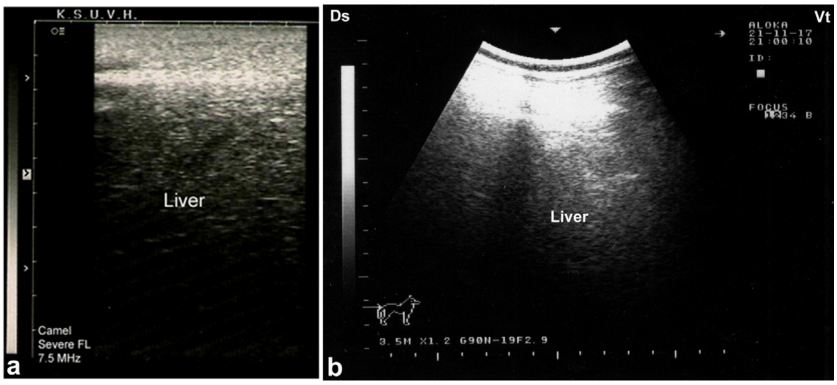

Fig. 12. Ultrasonogram of severe fatty degeneration in 2 camels. The transducer was placed in the 11th intercostal space using a 7.5 MHz linear transducer (a) and 3.5 MHz sector transduced (b). The liver is hyperechoic near the abdominal wall and cannot be visualized very far from the abdominal wall.

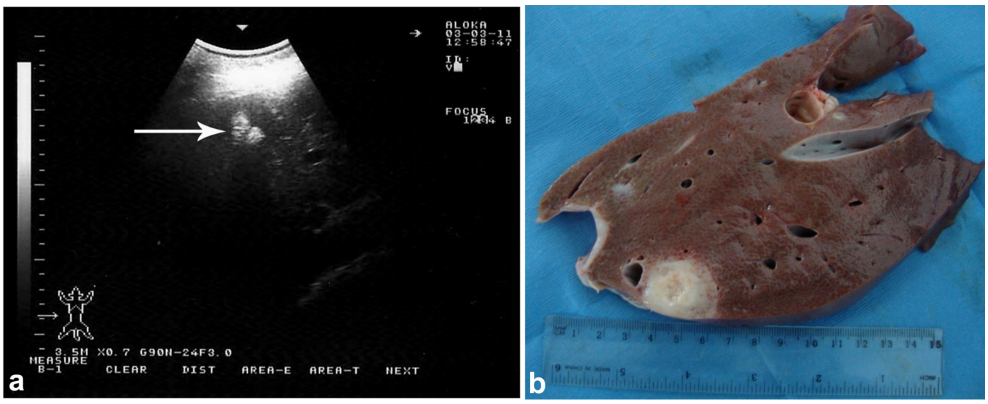

Fig. 13. Hepatic ultrasonogram of a hepatic abscess in a camel (arrow, a) which was detected at postmortem examination (b).

21 (18.9%) were more than seven years old [3]. In the later study, investigation of bacteria revealed 90 aerobic isolates; they were identified to 52 (57.8%) gram positive cocci, 20 (22.2%) gram positive rods and 18 (20.0%) gram negative rods. *Staphylococcus* spp. (41.1%), *Corynebacterium* spp. (17.9%) and *Streptococcus* spp. (13.3%) were the most frequently identified bacteria involved in liver abscesses of camels [3]. Ultrasonography reveals a hypoechoic or hyperechoic area depending on the stage of examination either acute or chronic stage (Fig. 13).

There is a high correlation for the occurrence of liver abscesses and ruminal pathology. Ruminal lesions resulting from acidosis are the predisposing factors for hepatic abscesses. Acid-induced ruminitis and damage of the protective surface are usually associated with

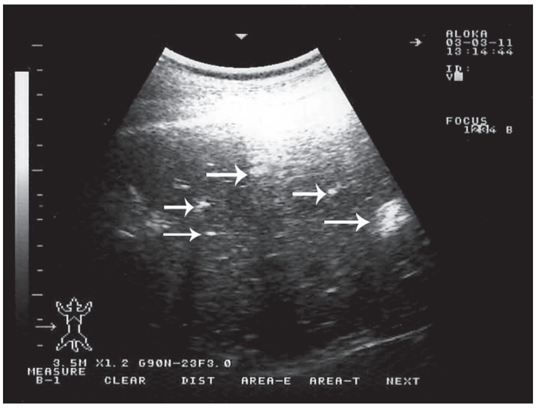

Fig. 14. Hepatic ultrasonogram of multiple hepatic abscesses of different sized in a camel. Differential diagnosis includes hepatic cirrhosis, calcified hydatid cysts, calcification of the bile ducts and hepatic tumors.

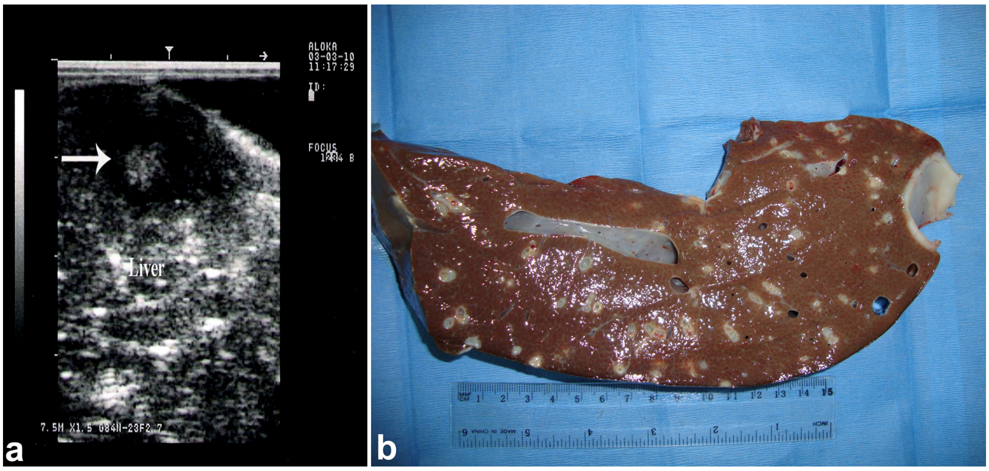

Fig. 15. Hydatid cyst in a camel liver. Image a shows ultrasonographic finding in a water bath for the distal part of the affected liver (b).

a sudden change to high-energy diets and other dietary indiscretions such as a change in feeding patterns. Bacteria from the portal circulation are filtered by the liver, leading to infection and abscess formation. Multiple hepatic abscessations can also be detected by ultrasonography (Fig. 14). Liver abscesses should be differentiated from hydatid cyst (Fig. 15).

CALCIFICATION OF THE BILE DUCT

Calcification of the bile ducts is a common finding in camel [2, 8, 10]. Calcified bile ducts are hyperechoic and are characterized by intense echoes accompanied by a distal acoustic shadow (Fig. 16).

CAUDAL VENA CAVA ABNORMALITIES

In healthy camels, the caudal vena cava (CVC) appears triangular in shape. However, the lumen of the CVC may be dilated and therefore imaged round to oval as a result of systemic venous congestion (Fig. 17). Causes of circulatory congestion include right-sided heart failure, thrombosis of the CVC, and compression of the CVC in the thorax or sub-phrenic region by space-occupying lesions [24, 40].

In conclusion, hepatic ultrasonography is a useful methodology for diagnosis and verification of liver diseases in camels. It also can be used for determining the prognosis and treatment outcome in such cases. This imaging modality can scan diffuse as well as focal hepatic lesions. Hepatic biopsy under ultrasound guidance can also be used for confirmation of hepatic lesions.

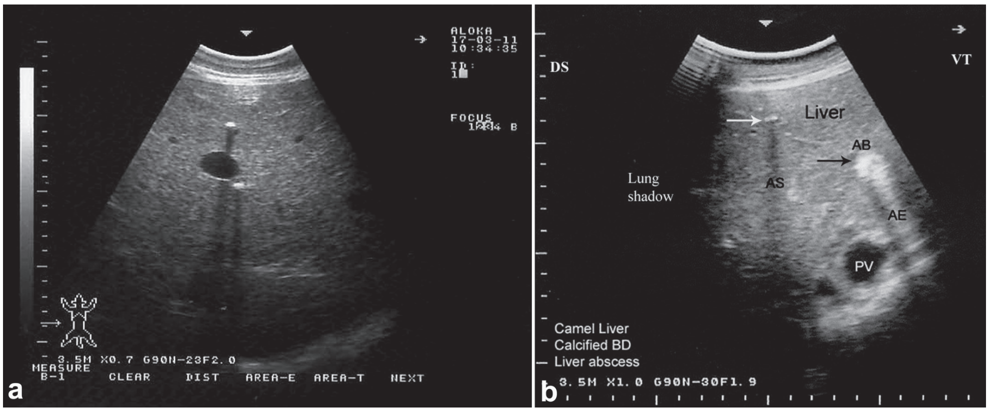

Fig. 16. Calcified bile ducts and hepatic abscess detected by ultrasonography in 2 apparent healthy camels. Intense echoes are imaged accompanied by a distal acoustic shadow (a, b). AS, acoustic shadowing; AB, abscess; PV, portal vein. Arrow in image (b) points to the calcified bile duct.

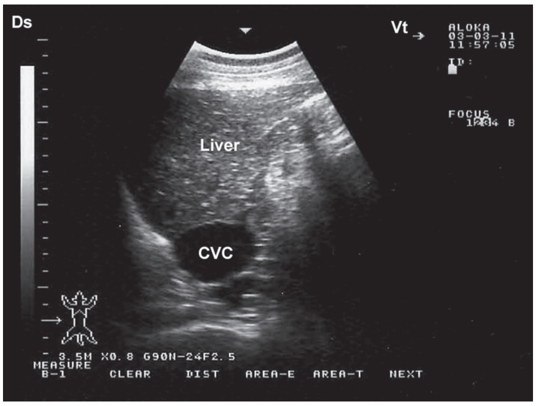

Fig. 17. Ultrasonogram of the caudal vena cava in a camel with systemic venous congestion due to cardiac insufficiency. Image was triangular from the 10th intercostal space. Ds, dorsal; Vt, ventral.

CONFLICT OF INTEREST. The author declares no conflict of interest related to this review article.

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