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Radiographic and ultrasonographic assessment of liver size in dogs with hepatic affections

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The study was conducted on 25 dogs suffering from hepatic affections i.e., hepatitis (n=17) and liver neoplasms (n=8) and included common breeds of dogs. The objective of the study was to establish radiographic and ultrasonographic morphometry of various liver lobes in dogs with hepatitis and liver neoplasms. The animals were evaluated on the basis of signalment, history, clinical signs, haematology, biochemistry, radiographic and ultrasonographic findings. Radiographic linear measurement of liver in lateral recumbency ranged from 8.23 cm to 20.02 cm for animals with hepatitis, and 9.02 cm to 19.10 cm for animals with suspected liver neoplasms. Evaluation of liver size by radiography was not a reliable method due to wide variations in the breed size. On the basis of ultrasonography mean size of liver lobe was 4.58±0.28 cm (range 3.98-12.98 cm) on the basis of 95% confidence interval irrespective of liver lobe for animals with hepatitis. The size of liver for animals suspected with liver neoplasm was 3.33±0.38 cm with 95% confidence interval (range 2.42-14.01 cm) irrespective of liver lobe. Reduced appetite, pale mucus membrane, fever, vomiting, anaemia, elevated liver function test enzymes such as AST, ALT, ALKP,GGT were hallmarks of hepatic affections like hepatitis and liver neoplasm in dogs. The correlation of history, clinical signs, haematology, biochemistry and ultrasonography findings aided in the diagnosis of hepatic affections in dogs.

***Key words**: Dog, Hepatic affections, Radiography, Ultrasonography*

The liver is the major organ involved in homeostasis and performs important functions like detoxification, digestion and immune surveillance. Various hepatic affections like hepatitis and hepatic neoplasms are responsible for non-accidental death in canines (Patel *et al*., 2022). The common changes observed in dogs suffering with various hepatic affections involve change in morphometry and appearance of liver. The use of non-invasive diagnostic techniques like ultrasonography (Center, 2009) and radiography (Partington and Biller, 1995) can be useful in estimation of liver size in dogs. No data is available regarding the radiographic and ultrasonographic morphometry of different lobes of liver in dogs suffering from various hepatic affections like hepatitis and liver neoplasms. The correlation of the haemato-biochemical findings with the ultrasonographic and radiographic findings may aid in the diagnosis of hepatic affections. Therefore, the present study was aimed with the objective of quantitative assessment of liver size in dogs with hepatic affections such as hepatitis and liver neoplasms using radiography and ultrasonography.

Material and Methods

The study was conducted on 25 dogs suffering from hepatitis (n=17) and suspected liver neoplasms (n=8). The animals were evaluated based on age (yr), breed (non-specific), body weight (kg), heart rate (beats/min), respiration rate (breaths/min), rectal temperature (°F) and colour of mucous membrane (pink/pale/congested). The animals were subjected to estimations of haemoglobin (Hg- g/dL), total leukocyte count (TLC-μL), packed cell volume (PCV-%), platelet count (10^3/μL) and differential leukocyte count (DLC-%) and liver function tests, which included aspartate transaminase (AST- U/L), alanine aminotransferase (ALT- U/L), alkaline phosphatase (ALP- U/L), gamma-glutamyl transferase (U/L), total bilirubin (mg/dL), total protein (g/dL) and albumin (g/dL). Radiographs of the abdomen were taken in left lateral, right lateral and ventro-dorsal recumbencies. The size of the liver was evaluated on the basis of extent of liver within or beyond the costal arch, gastric axis (parallel, cranial or caudal to corresponding rib), contour and margination of liver and radiographic linear measurements (cm) obtained from vertical and horizontal dimension of liver. The maximum vertical and horizontal dimension (cm) obtained from either left or right lateral radiographs were recorded. Ultrasonography of liver was done using Philips affinity 70 ultrasound machine with animals positioned in dorsal recumbency. The convex probe of frequency C5-1 MHz and linear probe of frequency L12-5 MHz were used. Liver dimensions in centimetre (cm) were recorded from the ventral border of liver to the tip of diaphragm in transverse and longitudinal planes for different lobes of liver (Barr, 1992). Maximum dimension (cm) obtained either in longitudinal or transverse scan was taken into consideration. The lobes of liver considered for taking dimensions were quadrate, left and right liver lobe. For caudate lobe, the area of extent of horizontal dimension and vertical dimension up to the right kidney were

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recorded. The mean±SE, 95% CI were calculated using SPSS 16.0 software.

Results and Discussion

The number of males with hepatitis (n=10) and suspected for liver neoplasm (n=5) were more in comparison to females. Patnaik *et al.* (1980) who also reported more predisposition of hepatocellular carcinomas in males. In contrast, earlier workers recorded higher incidence of females with bile duct carcinomas (Patnaik *et al*., 1980) and hepatitis (Bexfield *et al*., 2012). Hepatitis was confirmed in 17 dogs, which had a mean age of 5.68±0.69 yr. This was in contrast to Shih *et al*. (2007) who reported hepatitis in old aged dogs with a mean age of 9.3 yr. In the present study, liver neoplasm was suspected (n=5) or confirmed (n=3) in 8 dogs with mean age of 8.55±1.06 yr, which was similar to the findings of earlier workers (Patnaik *et al*., 1980; Evans, 1987; Hammer and Sikkema, 1995; Murakami *et al*., 2012; Schwarz *et al*., 1998; Crabtree *et al*., 2010). Mean±SE of body weight (kg) for animals with hepatitis and suspected liver neoplasm was 28.12±2.43 and 26.94±4.47 kg, respectively. Crabtree *et al*. (2010) recorded that mean body weight of dogs suffering with hepatic and splenic lymphoma was 25.52 kg. Labradors were the more commonly affected breed with hepatitis (n=7) and suspected liver neoplasms (n=2), which is in agreement with earlier reports (Shih *et al*., 2007; Bexfield *et al*., 2012; Shih *et al*., 2007; Crabtree *et al*., 2010; Murakami *et al*., 2012).

The heart rate (beats/min) and respiratory rate (breath/min) were elevated for all the affected animals than the normal reference range as also reported by Kahn and Line (2005) (Table 1). Among animals suffering from hepatitis (n=17), 11 animals had a history of vomiting, palpable abdominal mass was recorded in 1 animal, 1 had a history of long-term steroid use, 1 showed abdominal distension, 9 animals showed pale mucous membrane, 14 animals showed reduced appetite and 3 animals showed complete inappetence. Among the animals suspected for liver neoplasm (n=8), 5 animals had a history of vomiting, 4 had respiratory distress, 1 had abdominal distension, palpable abdominal mass was recorded in 2 animals. Evaluation of the mucous membrane in animals with suspected liver neoplasm revealed pale in 4, congested in 2 and normal in 2 animals. Reduced appetite was reported in all the 8 dogs suspected for liver neoplasm. All the animals had fever of varying degree. Similar findings were reported in dogs with hepatitis (Shih *et al*., 2007; Patel *et al*., 2022) and liver neoplasm (Evans, 1987; Murakami *et al*., 2012; Patel *et al*., 2022). However, Stowater *et al*. (1990) reported that liver neoplasms may be clinically inapparent and usually found as proliferative lesion at necropsy of old dogs. Abdominal palpation was not a reliable method for evaluation of liver size in dogs in the present study, which was in contrast with the earlier reports by Johnson and Sherding (1999).

Mean values for different haematological parameters and biochemical parameters are presented in table 1. The haemoglobin values were below the normal reference range in animals with hepatitis (8.88±1.10 g/dL) and suspected liver neoplasm (9.81±2.10 g/dL). Infection and neoplasm cells may cause inflammation, which results in lower production of red blood cell thus causing anaemia (Patel *et al*., 2022). However, Johnson and Sherding (2009) were of the opinion that anaemia occurs secondary to liver diseases due to blood loss or may

Table 1: Physical and haemato-biochemical findings in animals with hepatitis and suspected liver neoplasm.

Parameters	Hepatitis (n=17)	Suspected for liver neoplasm (n=8)
Heart Rate (beats / min)	164.18±2.59	164.88±3.07
Respiratory rate (per min)	18.65±0.59	17.13±0.90
Rectum temperature (°F)	103.41±0.13	103.12±0.19
Haemoglobin (g/dL)	8.88 ±1.10	9.81 ±2.10
Neutrophil (%)	89.64 ±1.84	82.29 ±3.48
Basophil (%)	0.00 ±0.00	0.00 ±0.00
Eosinophils (%)	0.00 ±0.00	0.57±0.57
Monocytes (%)	0.00 ±0.00	0.00±0.00
Lymphocytes (%)	10.36 ±1.84	17.14 ±3.23
Packed cell volume (%)	26.79 ±2.84	29.38 ±5.31
Platelets (10^3/ µL)	211.36 ±38.58	224.57 ±60.10
Total leukocyte count (per µL)	22913.08 ±3971.77	10898 ±2531.91
Aspartateaminotransferase (U/L)	128.70 ±50.18	50.20 ±8.86
Alanine aminotransferase (U/L)	218.17 ±71.18	71.60 ±7.02
Alkalinephosphatase (U/L)	630.92 ±129.56	238.33 ±41.25
GGT (U/L)	67.27 ±40.92	16.60±3.57
Total protein (g/dL)	6.03 ±0.43	6.77 ±0.41
Albumin (g/dL)	2.53 ±0.26	2.77 ±0.46
Total bilirubin (mg/dL)	2.51 ±0.95	0.22 ±0.03

be associated with normocytic normochromic anaemia which is seen in chronic disorders. The mean values for neutrophils were above the normal reference range for all the animals with hepatitis (89.64±1.84) and suspected liver neoplasm (82.29±3.48), which may be due to the presence of ongoing inflammation, infectious, necrolytic or diffused infiltrative hepatic disorders. Leukocytosis with neutrophilia was a common finding reported in hepatic neoplasms (Patnaik *et al*., 1980). Complete blood cell count abnormalities are reported to be associated with hepatobiliary disorders (Alvarez and Whittemore, 2009). Mean±SE value for lymphocytes was in normal range for animals suspected for liver neoplasm (17.14±3.23%), whereas it was below the normal reference range in animals with hepatitis (10.36±1.84%), which was indicative of lymphopenia. TLC was elevated above the normal reference range in animals suffering with hepatitis (22913.08±3971.77/μL), which might be due to ongoing infection. However, the values of TLC were within the normal reference range for animals suspected with liver neoplasms. Kumar *et al*. (2012) opined that it may be indicative of acute pancreatitis. Mean±SE values of PCV were below the normal reference for all the animals with hepatitis (26.79±2.84%) and suspected for liver neoplasm (29.38±5.31%), which might be due to low levels of haemoglobin and decreased production of red blood cells resulting from ongoing inflammation (Patel *et al*., 2022). Mean±SE value of platelets was in normal reference range for all animals with hepatitis (211.36±38.58×10^3/μL) and suspected liver neoplasm, 224.57±60.10 ×10^3/μL). This was in contrast with earlier reports where chronic liver disorders were associated with thrombocytopaenia due to depressed thrombopoietin levels, splenic sequestration and increased destruction of platelets (Neumann, 2006; Mitchell *et al*., 2016). However, in the present study thrombocytopenia was not seen. Johnson and Sherding (1999) suggested that platelet function defects are seen in dogs affected with various liver disorders and mucosal bleeding time may be used to check coagulopathy defects.

The values of liver enzymes such as aspartate aminotransferase, alanine aminotransferase, alkaline phosphatase and gamma glutamyl transferase were increased in all the animals with hepatitis and suspected liver neoplasm (Table 1). Center (2007) and Kumar *et al*. (2012) also reported similar findings. Increased level of AST, ALT, ALP and GGT in hepatic affections has been reported by earlier workers also (Neer, 1992; Hammer and Sikkema, 1995; Schwarz *et al*., 1998; Center, 2007; Pradhan *et al*., 2008; Shih *et al*., 2007; Murakami *et al*., 2012; Ko *et al*., 2020). Johnson and Sherding (1999) suggested that AST and ALT levels are elevated in case of injury to hepatocytes, and ALP and GGT are elevated in case of cholestasis. Mean±SE for bilirubin (mg/dL) was above the normal reference range for all the animals with hepatitis (2.51±0.95), which may be due to pathological condition of liver resulting in ineffective clearance of bilirubin or obstruction in the bile duct. However, in animals suspected for liver neoplasm, the bilirubin was within the normal reference range (Table 1). Increased level of bilirubin has been reported in dogs suffering from various hepatic neoplasms (Hammer and Sikkema, 1995; Murakami *et al*., 2012) and hepatitis (Shih *et al*., 2007). Johnson and Sherding (1999) reported that the increased level of bilirubin may occur secondary to haemolysis and cholestasis. The mean±SE values for albumin (g/dL) were in normal reference range for animals suspected for liver neoplasm (2.77±0.46) and below the normal reference range for animals with hepatitis (2.53±0.26). Hypoalbuminemia in dogs has been reported by earlier workers in hepatic affections like hepatitis (Shih *et al*., 2007) and hepatic neoplasms (Stowater *et al*., 1990).

In radiographs of 14/17 animals, the liver extended beyond the costal arch (Figs. 1 and 2). The gastric axis was caudally displaced and the pylorus was dorsally shifted in 12 cases. The liver margin was sharp and regular in 11 animals (Fig. 1) while in remaining 3 cases the liver had rounded but regular margins (Fig. 2). This suggested that liver was enlarged and had altered shape, size and margination. Out of the 8 animals suspected for liver neoplasm, radiography could be taken in 6 cases only. In all the 6 cases, the liver extended beyond the costal arch (Figs. 3 and 4). The gastric axis was caudally displaced and the pylorus was dorsally shifted in 4 cases (Figs. 3 and 4) and not appreciable in 2 animals. The liver margin was irregular in 3 animals (Fig. 3) while in remaining 3 cases the liver had rounded but regular margins (Fig. 4). Relation of the caudo-ventral tip of liver lobe beyond costal arch, contour and margination and caudally displaced gastric axis position were also reported earlier (Wrigley, 1985; Evans, 1987; Partington and Biller, 1995). Additionally, dorsally displaced pylorus was regarded as a radiographic feature of liver enlargement in dogs of the present study. Incidence of metastasis in the lungs (Fig. 3) was observed in 2 animals suspected for liver neoplasm, which was characterised by different/nodular interstitial pattern in the caudal lung lobes. This corroborated with the diagnosis of liver neoplasm in these dogs (Johnson and Sherding, 1999). Radiographic findings were corroborated with the haematology and biochemical findings, which further confirmed the liver pathology in all the animals with hepatitis and suspected liver neoplasm (Root, 1974). Radiographic measurements have not been found useful in evaluation of liver size in dogs (Bree and Sackx, 1987; Barr, 1992; Sharma *et al*., 2016; Kim *et al*., 2018). Linear measurements (cm) of liver obtained

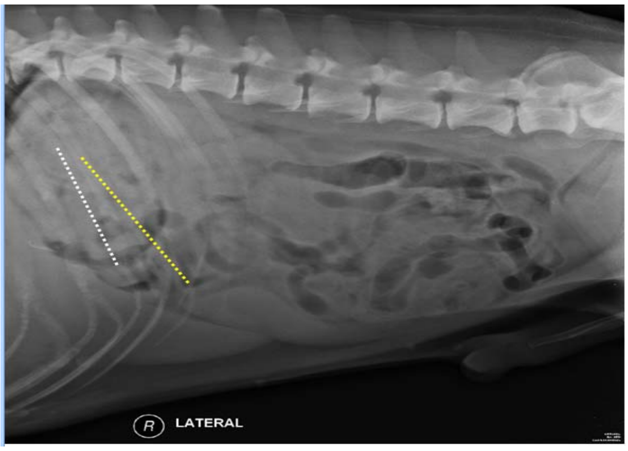

Fig. 1: Radiograph of cranial abdomen showing extent beyond costal arch, gastric axis (yellow line) caudally displaced to adjacent rib (white line), dorsally shifted pylorus, sharp and regular margins in an animal with hepatitis.

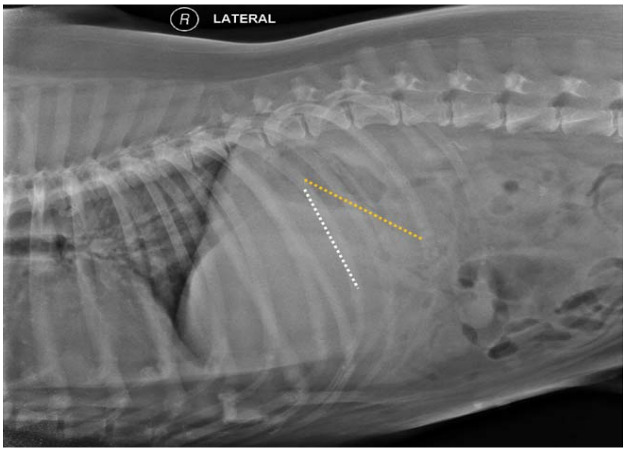

Fig. 2: Radiograph of cranial abdomen showing extent beyond costal arch, gastric axis (yellow line) caudally displaced to adjacent rib (white line), dorsally shifted pylorus and margins rounded and regular in an animal with hepatitis.

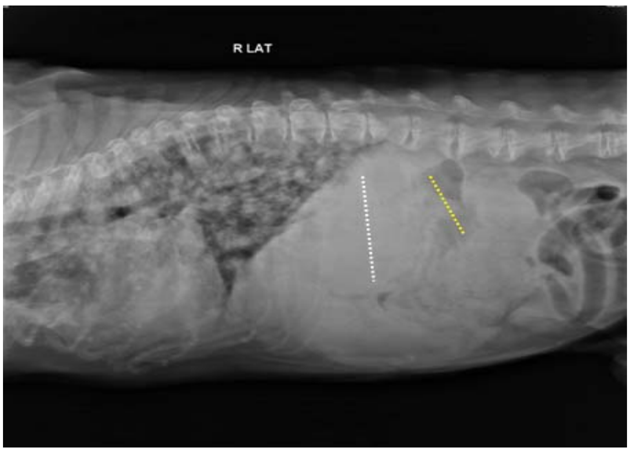

Fig. 3: Radiograph of cranial abdomen showing extent beyond costal arch, gastric axis (yellow line) caudally displaced to adjacent rib (white line), dorsally shifted pylorus, margins irregular and diffused interstitial pattern seen in lungs in an

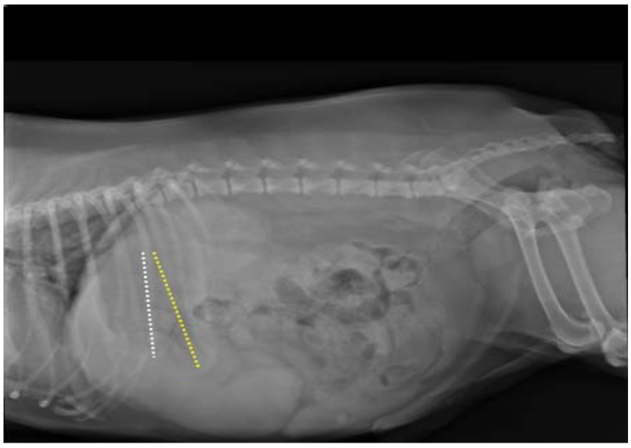

Fig. 4: Radiograph of cranial abdomen showing extent beyond costal arch, gastric axis (yellow line) caudally displaced to adjacent rib (white line), dorsally shifted pylorus and margins rounded and regular in an animal suspected for liver neoplasm.

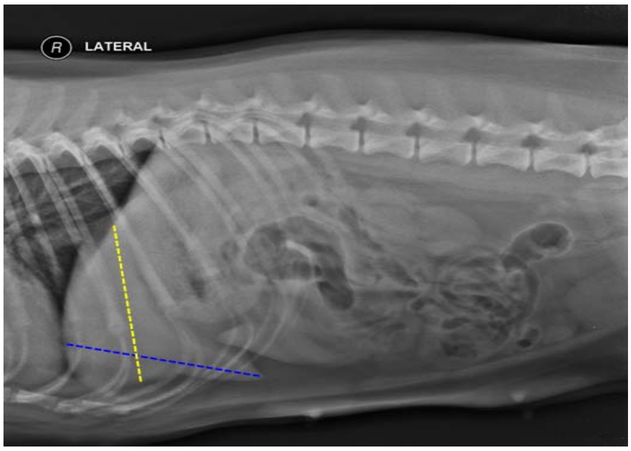

Fig. 5: Radiograph of cranial abdomen showing linear measurement of liver (blue: horizontal, yellow: vertical) in right lateral recumbency**.**

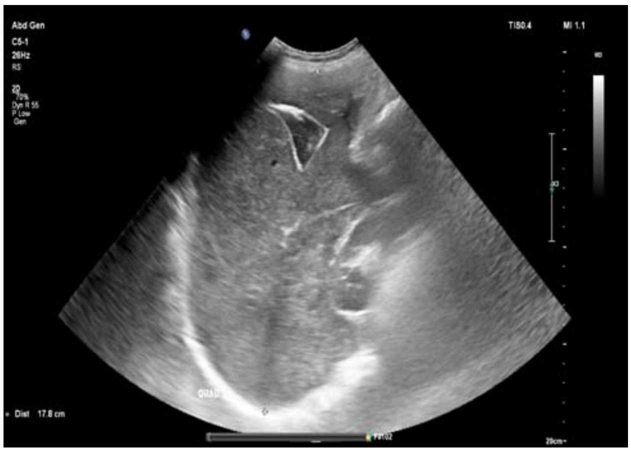

Fig. 6: Ultrasonography of quadrate liver lobe showing hyperechoic echotexture with dimension in cm (yellow line) in an animal with hepatitis.

Table 2: Liver lobe dimensions (cm) in animals with hepatitis and suspected liver neoplasm.

Liver lobe	**Hepatitis (n=17)**	**Suspected for liver neoplasm (n=8)**
Quadrate (cm)	9.29±0.67 (7.87-10.72)	9.15±1.05 (6.67-11.63)
Right liver lobe (cm)	9.71±0.52 (8.61-10.80)	9.17±1.03 (6.72- 11.61)
Left liver lobe (cm)	11.35±0.71 (9.85-12.86	10.06±1.61 (6.12-14.01)
Caudate Horizontal (cm)	5.50±0.39 (4.68-6.32)	4.89±0.63 (3.40-6.38)
Caudate Vertical (cm)	4.58±0.28 (3.98-5.18)	3.33±0.38 (2.42-4.23)

Values in parentheses indicate 95% confidence interval (CI) values

either in right or left lateral recumbency were recorded (Fig. 5). The vertical and horizontal dimensions for animals affected with hepatitis ranged from 9.21 cm to 15.73 cm and 8.23 cm to 20.02 cm, respectively, with a mean±SE of 12.56±0.57 cm for vertical dimension and 14.09±0.89 cm for horizontal dimension. Similarly, the vertical and horizontal dimension (cm) of animals suspected for liver neoplasm ranged from 9.02 cm to 16.67 cm and 10.67 to 19.1 cm, respectively with a mean±SE of 12.71±1.15 cm for vertical dimension and 14.35±1.34 cm for horizontal dimension. These measurements were similar to normal vertical and horizontal dimensions reported earlier (Singh *et al.*, 2023). Linear measurements were therefore not considered reliable as there were wide variations owing to the variations in breed and size of the animals. It was possible to record the dimension through ultrasonography reliably and repeatedly in all the animals. The mean±SE values of the dimensions (cm) for various lobes of liver along with their 95% confidence interval like quadrate lobe, left liver lobe, right liver lobe, caudate horizontal and vertical for animals with hepatitis and suspected for liver neoplasm are presented in table 2. The dimensions (cm) for liver lobe ranged from 5.50±0.39 cm to 11.35±0.71 cm irrespective of liver lobe in animals diagnosed with hepatitis. Similarly, the dimensions (cm) for liver lobe

Fig. 7: Ultrasonography of left liver lobe showing hyperechoic echotexture with dimension in cm (yellow line) in an animal with hepatitis.

Fig. 9: Ultrasonography of caudate lobe showing hyperechoic echotexture with dimension in cm (Red line: Horizontal; Blue line: Vertical) in an animal with hepatitis.

Fig. 8: Ultrasonography of right lateral liver lobe showing hyperechoic parenchyma with dimension in cm (yellow line) in an animal with hepatitis.

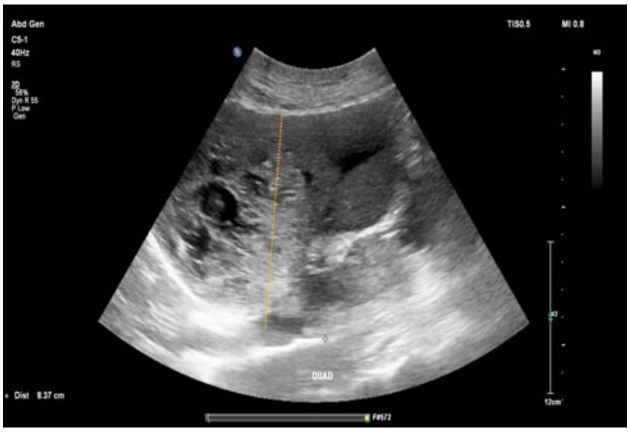

Fig. 10: Ultrasonography of quadrate liver lobe showing heterogenous echotexture with few hypoechoic/ cavitary lesions with dimension in cm (yellow line)

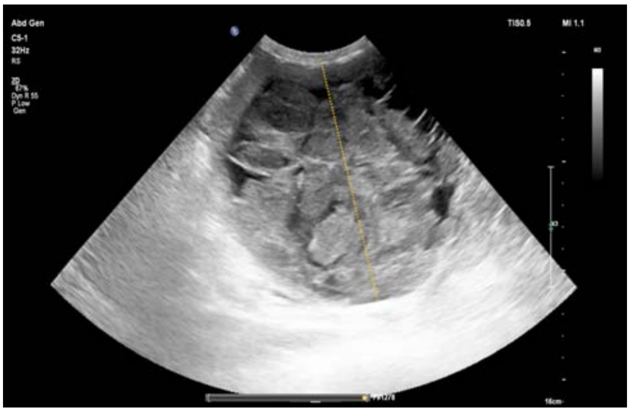

Fig. 11: Ultrasonography of left liver lobe showing heterogenous echotexture and irregular margins with dimension in cm (yellow line) in an animal suspected for liver neoplasm.

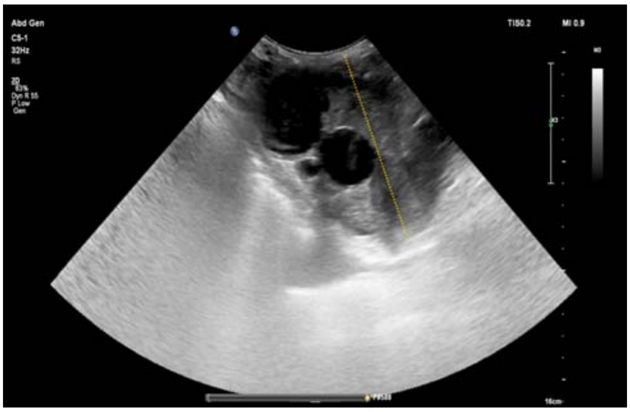

Fig. 12: Ultrasonography of right liver lobe showing circumscribed hypoechoic regions with dimension in cm (yellow line) in an animal suspected for liver neoplasm.

Fig. 13: Ultrasonography of caudate liver lobe showing heterogenous echotexture and irregular margins with dimension in cm (Red line: Horizontal; Blue line: Vertical) in an animal suspected for liver neoplasm.

ranged from 4.89±0.63 cm to 10.06±1.61 cm irrespective of liver lobe in animals suspected with liver neoplasm. These dimensions were considerably higher than those reported in healthy dogs by earlier workers (Singh *et al.*, 2023). The ultrasonographic findings corroborated with the biochemical findings, which further confirmed the liver pathology. Godshalk *et al.* (1988) reported the use of ultrasonography in the measurement of liver size in dogs by taking the measurement from the tip of the ventral lobe of liver to the diaphragm in transverse and longitudinal planes. Godshalk *et al.* (1988) reported the quantitative assessment of liver size through ultrasonography by taking the linear measurements and correlated the findings by multiplying or adding it with liver and body weight. The authors opined that ultrasonography was not reliable in the assessment of liver size in dogs. In contrast, Barr (1992) reported the same method of taking linear measurements of liver in live dogs followed by scanning of the same dogs post euthanasia. The authors found ultrasound to be reproducible and accurate in measuring the liver dimensions and liver weight of the dogs. In the present study, generalised increase in echotexture of hepatic parenchyma was observed in 10 animals suffering from hepatitis (Fig. 6-9). However, in the remaining 7 animals the size of liver was enlarged but the echotexture was normal when compared to splenic parenchyma and renal cortex. Hartzband *et al.* (1989) and Larson (2016) suggested that comparison of liver parenchyma with spleen and renal cortex is useful for evaluating liver disease. The liver margins were sharp in 6 animals. However, the remaining 11 animals showed round margins. All the animals showed altered echotexture of the liver parenchyma, which varied in combinations of heteroechoic, hypoechoic, hyperechoic, anechoic or normal (Figs. 10-13). The liver margins were irregular in all the animals. Altered echotexture in various hepatic affections like diffuse liver diseases, fatty change, hepatitis, liver neoplasms etc. had been reported by earlier researchers (Nyland and Park, 1983; Kumar *et al.*, 2012; Sharma, 2020). Fine needle aspiration cytology (FNAC) and biopsy samples in 4 cases suspected with liver neoplasm confirmed hepatocellular carcinoma. From this study it was concluded that both radiography and ultrasonography could be used to estimate the size of the liver in cases of hepatic dysfunction. However, ultrasonography was found to be a more valuable tool in evaluating the size of various liver lobes, and evaluating the changes in the liver parenchyma.

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