

Case Report**Shear Wave Elastography as a Diagnostic Tool for Feline Hepatic Lipidosis: A Case Report**

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Introduction

Hepatic lipidosis (HL) is one of the most common liver diseases in cats, but it usually develops after stress, anorexia, or underlying systemic diseases and is characterized by excessive lipid accumulation in hepatocytes (Barsanti et al., 1977; Watson, 2022). This condition can be progressive, and if left untreated, the mortality rate can reach up to 38% (Kuzi et al., 2017). Diagnosis involves the use of clinical findings, complete blood count (CBC), biochemical parameters, coagulation factors, imaging methods, and histopathological examinations (Watson, 2022). Although liver biopsy is considered the gold standard for evaluating

Abstract

Hepatic lipidosis (HL) is a common liver disorder in cats. Although histopathology remains the gold standard for diagnosis, there is a growing need for non-invasive diagnostic tools. This case report presents a geriatric cat diagnosed with HL, where hepatic parenchymal changes were evaluated using Shear Wave Elastography (SWE) and Computed Tomography (CT). SWE measurements revealed liver stiffness values of 30.42 kPa in the left lobe and 19.68 kPa in the right lobe, which are considerably higher than the reported reference ranges for healthy cats. CT imaging demonstrated decreased hepatic attenuation and hypodense areas consistent with lipid infiltration. In the precontrast phase, liver and spleen attenuation values were 44.37 HU and 55.84 HU, respectively, resulting in a liver-to-spleen (L/S) ratio of 0.79—below the established cut-off value associated with steatosis in human literature. A similar L/S ratio of 0.82 was observed in the contrast-enhanced portal venous phase. Histopathologic examination confirmed Grade 3 hepatic lipidosis, consistent with SWE and CT findings. This is the first case report to demonstrate the diagnostic utility of SWE in a cat with HL, suggesting its potential as a non-invasive and quantitative tool in clinical practice.

Key words: Tissue elasticity, liver steatosis, shear wave elastography, cat, computed tomography

hepatic lipidosis and fibrosis, its use is limited due to its invasive nature and risk of complications (Thampanitchawong & Piratvisuth, 1999; Pavlick et al., 2019; Kuwashiro et al., 2020). Therefore, as in human medicine, interest in non-invasive, safe, and repeatable diagnostic methods is increasing day by day in veterinary medicine. These diagnostic methods include serum biomarkers, conventional ultrasonography, and elastography. Elastography, in particular, is known to provide high specificity in detecting fibrotic changes in the liver (Castera et al., 2019; Castera, 2020; Berzigotti et al., 2021). Elastography is an ultrasound technique that measures tissue stiffness based on shear wave

velocity and provides a non-invasive assessment option. For this reason, it has become a widely used imaging method in both human and veterinary medicine in recent years (Redhu et al., 2015). Shear Wave Elastography (SWE) is widely used in human medicine, particularly for quantitative elasticity measurements in soft tissues such as the liver, kidney, thyroid, and breast (Puccinelli et al., 2023). In veterinary medicine, the use of SWE is becoming increasingly widespread; its effectiveness is being investigated in the diagnosis of renal parenchymal diseases, in addition to prostate, liver, lymph node, and breast tissues in dogs and cats (Ercolin et al., 2024; Feliciano et al., 2015; Febo et al., 2023). Recent studies have shown that quantitative SWE measurements of the liver are reliable and reproducible in healthy adult cats (Kim et al., 2020; Park et al., 2021).

This case report aims to evaluate the potential diagnostic value of SWE in revealing hepatic parenchymal changes in a geriatric cat diagnosed with hepatic lipidosis, in conjunction with computed tomography, histopathology, CBC, and biochemical analysis.

Case presentation

A 13-year-old, 4 kg, neutered male Domestic Shorthair cat was brought to the Internal Medicine Clinic at IUC Animal Hospital with complaints of anorexia, lethargy, icterus, and vomiting that had persisted for the past week. The medical history revealed that the clinical complaints began after different people visited the home and that the patient showed signs of stress. It was also learned that the cat had been fed low-quality commercial dry food for a long time and had lost weight significantly over the past 2-3 weeks (from 7 kg to 4 kg).

The physical examination revealed marked lethargy, dehydration (7%), and severely icteric mucous membranes. Body temperature, heart rate, and respiratory rate were observed to be within the normal reference range. The patient's skin examination revealed multifocal ecchymoses, thought to be related to coagulopathy secondary to hepatic dysfunction. Blood and urine samples were collected from the patient for laboratory testing. CBC (Idexx ProCyte Dx Haematology Analyser) and serum biochemistry analyses (Catalyst Dx Chemistry Analyser) were performed on the blood samples collected. As a result of the analyses,

neutrophilia, monocytosis, and thrombocytopenia were observed in the patient (Table 1). Serum biochemical analyses revealed elevated liver enzyme levels and hyperbilirubinemia. Additionally, Symmetric Dimethylarginine (SDMA), postprandial bile acids, and coagulation parameters were evaluated (Table 2).

Table 1. CBC analysis results of the patient.

Test	Result	Unit	Reference Range
RBC	8,94	M/ μ L	6.54-12.20
Haematocrit	42,9	%	30.3-52.3
Haemoglobin	14	g/dL	9.8-16.2
MCV	48.0	fL	35.9-53.1
MCH	15.7	pg	1.8-17.3
MCHC	32.6	g/dL	28.1-35.8
RDW	23.4	%	15.0-27.0
Reticulocytes	19.7	K/ μ L	3.0-50.0
Reticulocyte Haemoglobin	17.5	pg	13.2-20.8
WBC	17.10	K/ μ L	2.87-17.02
Neutrophils	10.31	K/ μ L	2.30-10.29
Lymphocytes	4.48	K/ μ L	0.92-6.88
Monocytes	1.99	K/ μ L	0.05-0.67
Eosinophils	0.21	K/ μ L	0.17-1.57
Basophils	0.11	K/ μ L	0.01-0.26
Platelets	47	K/ μ L	151-600
MPV	14.1	fL	11.4-21.6
Plateletcrit	0.07	%	0.17-0.86

RBC, red blood cells; MCV, mean corpuscular volume; MCH, mean corpuscular haemoglobin; MCHC, mean corpuscular haemoglobin concentration; RDW, red cell distribution width; WBC, white blood cells; MPV, mean platelet volume. Reference ranges correspond to the analyser manufacturer's feline reference intervals.

A complete urinalysis revealed +3 bilirubin and +2 protein. Urine specific gravity was measured at 1.020. Microscopic examination of the urine sample showed 4-5 leukocytes, numerous erythrocytes, and 10-12 renal epithelial cells in each field.

Abdominal ultrasonographic evaluation was performed using a Resona i9 (Mindray, China) ultrasound device and a convex probe with a frequency range of 3.0–11.0 MHz compatible with the device. The ultrasonographic examination revealed that the liver parenchyma was hyperechoic compared to the falciform fat tissue and showed a marked increase in echogenicity compared to the

spleen and left renal cortex. In addition, there was a localized increase in echogenicity anterior to the gallbladder, and the hepatic vein borders could not be identified due to the increase in parenchymal echogenicity.

Table 2. Serum biochemistry and coagulation parameters of the patient.

Test	Result	Unit	Reference Range
Glucose	129	mg/dL	71 - 159
Creatinine	1,1	mg/dL	0.8 - 2.4
Urea	20	mg/dL	16 - 36
BUN:Creatinine Ratio	18	-	-
Phosphorus	4,4	mg/dL	3.1 - 7.5
Calcium	8,8	mg/dL	7.8 - 11.3
Total Protein	7	g/dL	5.7 - 8.9
Albumin	2,8	g/dL	2.3 - 3.9
Globulin	4,2	g/dL	2.8 - 5.1
Albumin:Globulin Ratio	0,7	-	-
ALT	773	U/L	12 - 130
ALP	461	U/L	14 - 111
GGT	25	U/L	0 - 4
Bilirubin - Total	2,8	mg/dL	0.0 - 0.9
Ammonia	62	µmol/L	0 - 95
Cholesterol	168	mg/dL	65 - 225
Bile Acids Postprandial	144,9	µmol/L	0.0 - 14.9
D-Dimer	147	ng/mL	0-250
Prothrombin Time (PT)	11	sec	9-11
Activated Partial Thromboplastin Time (aPTT)	27	sec	12-17
Fibrinogen	140	mg/dL	150-300
Factor VIII	56	%	60-172
SDMA	16	ug/dL	0-14

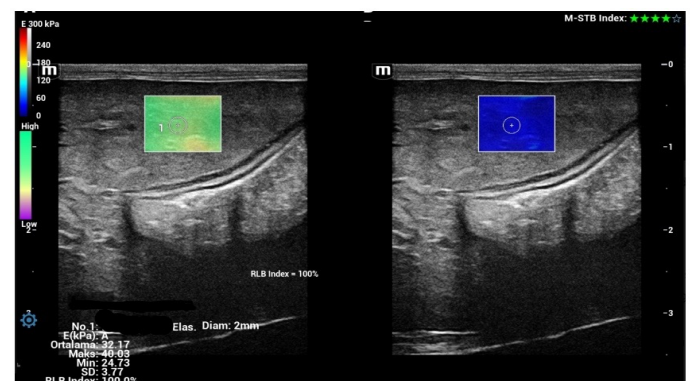
BUN, blood urea nitrogen; ALT, alanine aminotransferase; ALP, alkaline phosphatase; GGT, gamma-glutamyl transferase; SDMA, symmetric dimethylarginine; PT, prothrombin time; aPTT, activated partial thromboplastin time. Reference ranges are based on the analyser manufacturer's feline reference intervals.

The liver parenchyma exhibits heterogeneous echogenicity, consistent with findings of diffuse increased echogenicity in the liver. However, the gallbladder contents are anechoic and considered normal in appearance. No turbulent flow was detected on portal vein Doppler examination. Portal

vein flow velocity (PVmax × 0.57) was measured as 11.9 cm/s. The sizes of both kidneys were 3.84 cm x 2.42 cm on the right and 4.00 cm x 2.53 cm on the left; the mean resistive index (RI) measured from the left renal interlobar artery was found to be 0.76. No pathological formations were observed in the spleen or mesenteric lymph nodes.

After ultrasonographic evaluation, SWE procedures were performed. Measurements were taken of the right and left lobes of the liver, accessed via the xiphoid region, using an ultrasound device (Resona I9 Diagnostic Ultrasound System, Mindray®, China) and a linear probe compatible with the device with a frequency range of 6.0–23.0 MHz. Measurements were performed in dual-screen mode, accompanied by color and dispersion maps; 2 mm diameter Regions of Interest (ROI) were placed in parenchymal areas color-coded according to elasticity levels. Only images with a 100% stability index and a 5-star reliability level were included in the analysis. The average elasticity value calculated from five reliable images obtained from the left liver lobe was determined to be 30.42 kPa, while the value obtained from the right lobe was 19.68 kPa (Figure 1). Elastography measurements were also taken from the spleen and kidney cortex. The left kidney measured 30.64 kPa, the right kidney measured 31.41 kPa, and the spleen measured 23.95 kPa.

Figure 1. Shear wave elastography (SWE) of the feline liver.

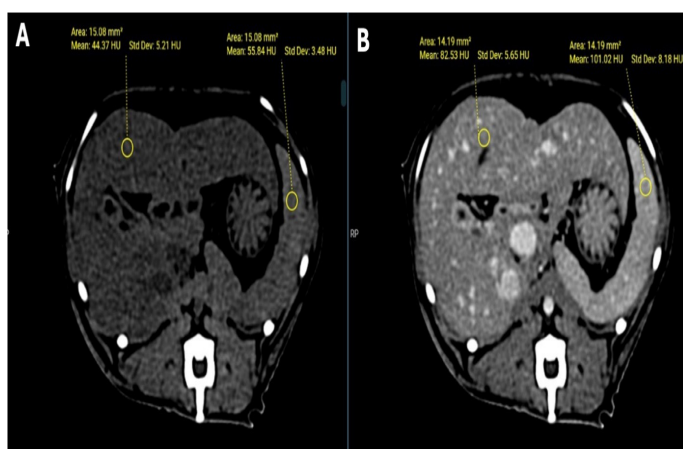


Two-dimensional shear wave elastography images obtained from the left hepatic lobe of a cat diagnosed with hepatic lipidosis. A circular region of interest (ROI; diameter 2 mm) was placed within the hepatic parenchyma. The elastography map demonstrates increased tissue stiffness, with a mean elasticity value of 32.17 kPa (range: 24.7–40.0 kPa). Only measurements with a reliability index of 100% and a five-star stability index were included in the analysis.

Abbreviations: SWE, shear wave elastography; ROI, region of interest; kPa, kilopascal.

Following elastography, the necessary consent was obtained from the patient's owner, and the patient was placed under general anesthesia. Written informed consent was obtained from the owner for all diagnostic and invasive procedures. An incisional biopsy was planned after computed tomography (CT) imaging. For premedication and analgesia, Butorphanol (Butomidor®; Richter Pharma AG, Feldgasse, Austria) was administered intravenously at a dose of 0.4 mg/kg. General anesthesia induction was achieved with intravenous administration of Propofol (Lipuro 1%®; Braun, Germany) at a dose of 4 mg/kg. Following endotracheal intubation, the patient was connected to the anesthesia machine via a rebreathing anesthesia circuit (Wato EX-35 Anesthesia Machine; Mindray, China). General anesthesia was maintained with Isoflurane (Forane®; Abbott, Switzerland) at a minimum alveolar concentration of 1.5%. The patient's vital signs were monitored throughout the procedure using a conventional bedside monitor. The patient was administered contrast-enhanced CT of the abdomen and portal angiography under general anesthesia. Liver dimensions were within normal limits, but hypodense nodular areas that did not enhance in the late venous phase were observed in the liver parenchyma, the largest of which was 9 mm in size in the lateral segment of the left lobe. At the same time, liver density was observed to be lower than normal due to fatty infiltration (Figure 2).

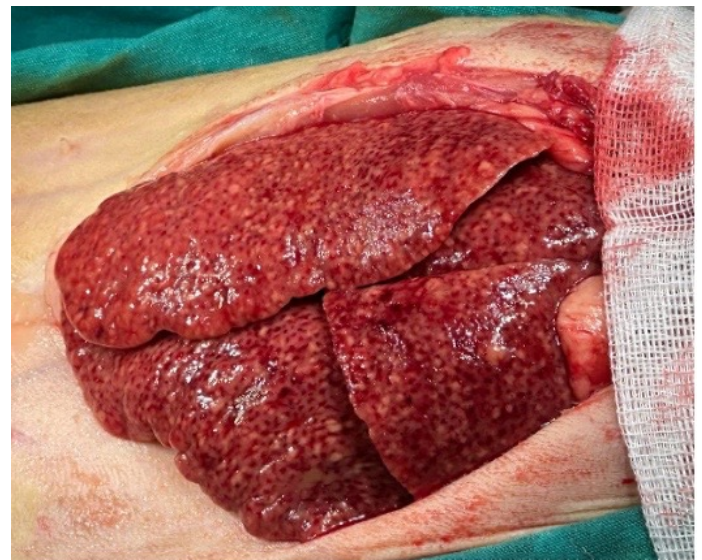
Figure 2. Abdominal CT images.



Panel A shows the pre-contrast axial image, and Panel B demonstrates the contrast-enhanced portal venous phase. Regions of interest (ROIs) were placed within the hepatic parenchyma and the spleen on both images to obtain attenuation measurements expressed in Hounsfield units (HU). The spleen was used as the reference organ for comparison of hepatic attenuation values. Abbreviations: CT, computed tomography; ROI, region of interest; HU, Hounsfield unit.

Following the CT scan, the patient was prepared for an incisional biopsy. For this purpose, the patient was placed in the dorsal position, the median laparotomy site was shaved, and asepsis and antisepsis were ensured. An incision was made along the median line from the xiphoid process to the umbilicus through the skin, abdominal muscles, and peritoneum, exposing the liver. Based on CT and ultrasound findings, an incisional biopsy was performed by performing a wedge resection from the peripheral segment of the left lobe (Figure 3). After bleeding control was achieved, the peritoneum, abdominal muscles, and skin were closed routinely. The biopsy material was sent for histopathological examination. The histopathological evaluation revealed Grade 3 hepatic lipidosis.

Figure 3. Intraoperative gross appearance of the liver.



Discussion

Hepatic lipidosis is the most common liver disease in cats, accounting for approximately 50% of histological examinations. It is often caused by anorexia, which leads to a negative energy balance, particularly in overweight cats, resulting in HL (Kuzi et al., 2017). In this case, it is thought that the stress experienced by the cat and the accompanying anorexia caused the disease to develop. It has been reported that mild to moderate non-regenerative anemia may be observed in the CBC of cats diagnosed with HL (Webb, 2018). In this case, no anemia was observed in the CBC. Biochemical investigations showed hyperglycemia, hypoalbuminemia, and low BUN levels. It has been reported that ALP activity is significantly elevated in most cases, ALT and AST

activities are generally mild to moderate, and GGT levels are rarely elevated (Webb, 2018; Abdellah et al., 2024). In biochemical analyses, contrary to previous reports, ALP levels were found to be high but lower than ALT and AST levels. While there is a slight increase in bilirubin levels, GGT, albumin, glucose, and urea levels are within reference ranges. (Table 1) In cases of HL, hepatomegaly may be seen on abdominal radiographs, but this is a relatively subjective and non-specific finding. Ultrasonographic examinations have found that hepatic hyperechogenicity relative to falciform fat has positive predictive value in the diagnosis of severe HL cases (Webb, 2018). Ultrasonographic examinations performed in this case revealed diffuse echogenicity increase, consistent with hepatic lipidosis. However, in a retrospective study on the differentiation of diffuse liver diseases in cats using ultrasonographic criteria, the overall accuracy rate of ultrasonography was found to be below 60%. Although classification accuracy in hepatic lipidosis cases exceeded 70% in some observers, this result was not considered clinically sufficient, and cytological or histopathological examinations were found to be necessary for a definitive diagnosis (Feeney et al., 2008). Fine needle aspiration under ultrasound guidance is frequently performed on the liver. However, in cases of suspected idiopathic HL, cytology may be misleading as nodular, localized, or multifocal infiltrative lesions may be overlooked (Webb CB. 2018). Liver biopsy is known to be the gold standard for evaluating hepatic lipidosis and fibrosis (Pavlick et al., 2019). However, the use of an automatic Tru-cut biopsy is not recommended in cats (Proot & Rothuizen, 2006). In a study examining the reliability of percutaneous liver biopsy, the major bleeding rate was reported as 56.7% and the complication rate as 16.7%; complications were more common in cats that were anemic or had a histopathological diagnosis of lipidosis (Pavlick et al., 2019). In this case, laparotomy was performed at the owner's request for a definitive diagnosis, and a sample was sent for histopathological examination after macroscopic suspicion of hepatic lipidosis.

Elastography has been extensively researched in recent years as an alternative to biopsy because it offers the ability to assess tissue mechanical properties non-invasively. This method provides both qualitative and quantitative diagnostic

information by utilizing changes in soft tissue elasticity in different pathologies (Sigrist et al., 2017). In shear wave elastography, the force transmitted to the tissue by focused high-intensity ultrasound pulses creates shear waves that propagate at a speed of 1–10 m/s and rapidly attenuate; the propagation speed (c) of these waves is directly proportional to tissue stiffness, expressed in kPa (Redhu., 2015). It has been accepted as a valuable method for the diagnosis of liver steatosis, fibrosis, and neoplasms in humans (Zaleska-Dorobisz et al., 2013). Furthermore, its effectiveness has been demonstrated in the evaluation of hepatic fibrosis in dogs, the differentiation of benign and malignant mammary tumors, and the diagnosis of testicular pathologies (Tamura et al., 2019). Studies have also been conducted using shear wave imaging in organs such as the spleen, kidney, mammary gland, and testis in cats (Thanaboonipat et al., 2019; Appleby et al., 2023). Studies have shown that elastography (E , kPa) values in the renal cortex of cats with chronic kidney disease (CKD) positively correlate with histopathological fibrosis and biochemical dysfunction (Thanaboonipat et al., 2019). These findings suggest that quantitative assessment of liver parenchyma using 2D-SWE in cats with hepatic lipidosis/fibrosis may be a reliable non-invasive marker reflecting the severity of fibrosis.

In a study investigating the effectiveness of two-dimensional shear wave elastography (2D-SWE) in the diagnosis of hepatic fibrosis in dogs, it was reported that median shear wave velocity (SWV) values (2.04 m/s) were significantly higher in dogs with clinically significant fibrosis compared to the control group (1.51 m/s) (Tamura et al., 2019). These findings support the use of elastography as an alternative diagnostic method for evaluating liver parenchymal diseases. In human studies of nonalcoholic fatty liver disease (NAFLD), tissue stiffness was reported to be significantly increased in individuals with steatosis; therefore, elastography may be a quantitative indicator reflecting the degree of steatosis (Cassinotto et al., 2021; Seo et al., 2023). Hepatocyte lipid accumulation in hepatic lipidosis in cats shows morphological features similar to simple steatosis in NAFLD; therefore, the sensitivity of elastography in measuring the degree of steatosis may also be valid for identifying cats with lipidosis.

Although there are no studies evaluating tissue stiffness in cats with hepatic lipidosis, there are studies evaluating liver elastography in healthy cats and cats not under sedation. These studies have demonstrated that tissue stiffness can be measured in organs such as the liver, spleen, and kidneys, thereby providing reliable baseline reference values independent of disease status (Kim et al., 2020; White, 2014; Park, 2021). The liver elastography values obtained in this case presentation were found to be 19.68 kPa for the right lobe and 30.42 kPa for the left lobe, which were significantly higher than the average range of 6.94–7.90 kPa reported in healthy adult cats (Kim et al., 2020). These findings indicate that increased elasticity in the parenchymal tissue can be detected non-invasively in the presence of hepatic lipidosis. The histopathological evaluation showing Grade 3 steatosis was consistent with the high kPa values measured by elastography (Seo et al., 2023). These results support the quantitative monitoring of fibrotic and steatotic changes in hepatic tissue without the need for liver biopsy. However, the stable measurement results obtained without a sedation protocol in this case demonstrate that sedation, which is recommended to limit measurement variability, is not necessary; however, the use of a standard protocol may still improve measurement consistency. The most frequently identified finding on computed tomography in cases of hepatic lipidosis in cats is diffuse density reduction in the liver parenchyma. In the presented case, the HU value of the liver was measured as 44.37. In healthy cats, the average liver HU value has been reported as 54.7 ± 5.6 (Heo et al., 2018). In studies conducted in humans, it has been reported that the parameter with the highest diagnostic accuracy in determining whether macrovesicular steatosis is above 30% is the liver/spleen (L/S) attenuation ratio obtained by CT, using ROC analysis. A cut-off value of 0.90 for this parameter yielded 79% sensitivity and 98% specificity, emphasizing that the L/S ratio is a reliable indicator for assessing hepatic steatosis (Rogier et al., 2015). In this case, the hepatic and splenic attenuation values measured in the pre-contrast phase were 44.37 HU and 55.84 HU, respectively, and the L/S ratio calculated based on these data was found to be 0.79. This value is below the threshold defined in the human literature for the presence of steatosis and is consistent

with findings in favor of steatosis. In the contrast-enhanced portal venous phase, hepatic and splenic HU values were measured as 82.53 HU and 101.02 HU, respectively, and the L/S ratio for this phase was calculated as 0.82. Although contrast-enhanced CT phases are not directly used in the quantitative assessment of steatosis, the finding of lower liver attenuation than the spleen in both phases supports the CT pattern consistent with steatosis defined in human studies. Diffuse hypodensity in CT findings, when evaluated together with elastography data, has been shown to increase the diagnostic accuracy of the multimodal imaging approach.

Conclusion

Shear Wave Elastography is a promising imaging technique that enables quantitative assessment of liver parenchymal tissue as an alternative to invasive methods. This case report demonstrates that the increase in tissue stiffness detected by SWE in a cat diagnosed with hepatic lipidosis significantly correlates with histopathological findings. Our findings suggest that SWE may be a potential diagnostic tool not only for the non-invasive detection of hepatic steatosis but also for staging and monitoring the disease. In this regard, large-scale, prospective studies covering cases of hepatic lipidosis and fibrosis at different stages are needed to more clearly establish the reliability, reproducibility, and prognostic value of SWE.

Ethical statement

This case report did not require ethical committee approval, as routine treatment protocols were followed.

Conflict of Interest

No conflicts of interest have been declared.

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