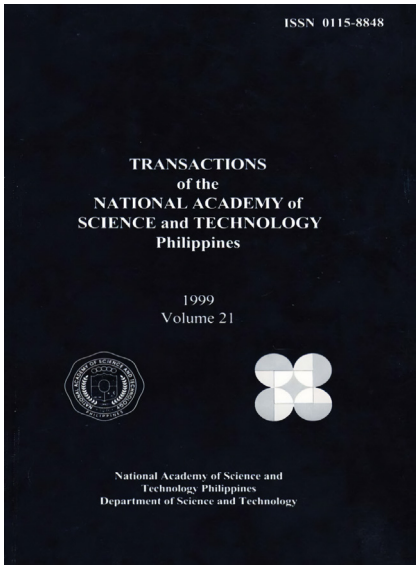
TRANSACTIONSNASTPHL
ISSN 0115-8848 (print)
ISSN 2815-2042 (online)

https://transactions.nast.ph/
Vol. 21 (1999)
doi.org/10.57043/transnastphl.1999.5759

Transactions NAST PHL, is the official journal of the National Academy of Science and Technology Philippines. It has traditionally published papers presented during the Academy's Annual Scientific Meeting since 1979 to promote science-based policy discussions of and recommendations on timely and relevant national issues as part of its functions as a national science academy. Starting in 2021, this journal has been open to contributions from the global scientific community in all fields of science and technology.



Diagnosis of Diffuse Hepatocellular Disorders in Dairy Cattle Through Ultrasonography and Digital Analysis

Jezie A. Acorda

College of Veterinary Medicine
University of the Philippines Los Baños, College, Laguna 4031

Citation
Acorda JA. 1999. Diagnosis of diffuse hepatocellular disorders in dairy cattle through ultrasonography and digital analysis. Transactions NAST PHL 21: 263-277. doi.org/10.57043/transnastphl.1999.5759

Trans. Natl. Acad. Sci. Tech. Philippines 21: 263-277 (1999).
ISSN 0115-8848

DIAGNOSIS OF DIFFUSE HEPATOCELLULAR DISORDERS IN DAIRY CATTLE THROUGH ULTRASONOGRAPHY AND DIGITAL ANALYSIS

JEZIE A. ACORDA
College of Veterinary Medicine
University of the Philippines Los Baños, College, Laguna 4031

ABSTRACT

Current diagnosis of liver disorders in cattle through clinical signs and biochemical analysis is not very accurate. In this study, evaluation of diffuse hepatocellular disorders in 226 Holstein-Friesian dairy cattle was conducted using ultrasonography and computerized analysis of ultrasonograms (digital analysis). Different echo patterns were distinguished, namely: bright pattern (BP), deep attenuation, vascular blurring and blurring of edges (BE) in fatty change of the liver; dark pattern and BE in hydropic degeneration; and BP in amyloidosis and hepatic dystrophy. In digital analysis of hepatic B-mode ultrasonograms, low echo means in hydropic degeneration, steep decline of echo means in fatty change, and high initial echo mean for hepatic dystrophy and amyloidosis were observed. The combination of ultrasonography and digital analysis provided a relatively more accurate method of diagnosis of diffuse hepatocellular disorders in dairy cattle.

Key words: amyloidosis, cattle, digital analysis, fatty change, hepatic dystrophy, hydropic degeneration, liver, ultrasonogram, ultrasound

INTRODUCTION

Diagnosis of hepatocellular disorders in dairy cattle is relatively difficult. The problem lies not only on the relative inaccessibility of the liver for examination, but most importantly on the multiple functions the liver performs. Thus, primary disorders of the liver can cause disorders in other regions of the body and disorders in other organs and tissues of the body can likewise cause secondary disorders in the liver.

Presently, diagnosis of hepatocellular disorders in dairy cattle has been made mainly on the bases of clinical signs, biochemical analysis and examination of biopsy tissue. Biopsy combined with examination of biopsy tissue, however, cannot be used routinely for diagnosis. In humans, although advanced diagnostic proce-

dures, including imaging techniques have been used, these methods, particularly, ultrasonography has not been applied widely in animals, especially in dairy cattle.

Diagnostic ultrasound or ultrasonography is one of the emerging imaging diagnostic tools that is currently being applied in both small and large animals. It is less invasive and has no danger of radiation, as compared with x-ray but with comparable resolution and accuracy. In many cases, the real-time capability of diagnostic ultrasound is better than that of x-ray. Ultrasonography is a technique used to locate or delineate deep tissues or structures by measuring the transmission or reflection of ultrasonic waves. It is a relatively safe, rapid, non-invasive procedure with high penetration and resolution used to image tissues and organs, in both animals and man. In addition, no special shields or building construction are required and many of the current instruments are portable (Cartee, 1981).

Computer analysis of ultrasonographic echoes, including digital analysis, has been used in humans in the diagnosis if diffuse disorders of the liver. Computerized ultrasound examination yields more information from the ultrasound image than normal observation, leading to increased diagnostic accuracy (Haberkorn *et al.*, 1989). Digital analysis can quantify the ultrasonogram images and assist in more objective analysis of lesions leading to more accurate diagnosis. Knowledge of this emerging technology is essential in diagnosis of diseases and disorders in both small and large animals.

The study was conducted to evaluate the usefulness of ultrasonography in combination with digital analysis in diagnosing hepatocellular diseases in dairy cattle.

MATERIALS AND METHODS

Animals

Two hundred and twenty-six (226) Holstein-Friesian dairy cattle, suffering from various disorders, aged 2-13 years old were used in the study. Of the 226 animals, 105 had locomotor disorders, 58 had reproductive disorders 32 had digestive disorders, 14 had nervous disorders, 8 had respiratory disorders, 7 had cardiac disorders and 2 had renal disorders.

Ultrasonography of liver of dairy cattle

The site for ultrasonography was prepared by shaving the upper and middle third regions of the last two intercostal spaces of the right flank of the animal. Aquasonic coupling gel (Echo Jelly®, Aloka Co. Ltd., Tokyo, Japan) was then applied and ultrasonography performed using a commercially available gray scale sonograph machine (Hitachi EUB-200V®, Hitachi Medical Corp., Tokyo, Japan) equipped with a 3.5 MHz transducer and a linear array electronic scanner.

The liver was imaged from the right side in the 11th and 12th intercostal spaces, just dorsal to the boundary between the upper and middle third of the rib. Constant imaging parameters (time gain compensation, gain, contrast, brightness

and dynamic range) were used. The machine power output and time gain compensation were fixed at main gain = 50 dB, near gain = 15 dB and far gain = 5 dB.

The B-mode ultrasonograms were recorded using a commercially-available still video (Still Video 1000MH®, Fujix, Fuji Photo Film Co. Ltd., Tokyo, Japan). A-mode ultrasonographic images of the liver were obtained using an image analysis software (Image Command 4198, TV Image Processor 4100®, Excel Application Software, Japan Avionics Co., Tokyo, Japan) for comparison with hepatic B-mode ultrasonograms.

After viewing all the ultrasonograms several times, the different ultrasonographic features were noted. Hepatic ultrasonograms were evaluated according to parenchymal echo characteristics, beam penetration, vascularity and hepatic edge visibility. The presence of the following were noted in individual ultrasonograms: a) hyperechoic areas scattered in the hepatic parenchyma (bright pattern); b) hypoechoic areas uniformly distributed in the parenchyma (dark pattern); c) hypoechoic areas in the distal region of the ultrasonogram (deep attenuation); d) diminished visibility of portal and hepatic veins (vascular blurring; and e) diminished visibility of the distal boundary of the hepatic parenchyma, i.e. the visceral surface of the caudate lobe (blurring of edges).

Hyperechocity and hypoechocity were determined subjectively based on whether the image of the liver was brighter or darker than the general average hepatic ultrasonogram. The evaluation of the ultrasonogram was made before histopathologic results were obtained.

Histopathological examination of liver samples

After ultrasonography, the animal was immediately slaughtered and liver and kidney samples were collected from the areas where the ultrasonograms were supposed to have been taken. The samples were immediately placed in 10% buffered formalin solution. Two specimens for the liver were prepared, one for staining with hematoxylin-eosin (H-E) and one for lipid staining. For H-E staining, the liver and kidney specimens were cut into small pieces (1.5×1.5×0.5 cm), and prepared according to standard histopathological procedures.

A portion of the liver histologically diagnosed as being characterized by fatty change was cut into a 1.0×1.0×0.2 cm piece and fixed in osmic acid-potassium dichromate solution for 72 hours and prepared histopathologically according to standard procedures. The specimens were then recorded by still video (Still Video 1000MH®, Fujix, Fuji Photo Film Co. Ltd., Tokyo, Japan) through a TV-microscopic camera (Camera Head HV-132®, Hitachi Denshi, Ltd., Tokyo, Japan) and the fatty occupying rate of the liver was calculated using a concentration measurement program of an image analysis software (Image Command 4198, TV Image Processor 4100®, Excel Application Software, Japan Avionics Co., Tokyo, Japan). The fatty occupying rate of the liver was determined histologically as the percentage of the area of the hepatic lobule stained with osmic acid-potassium dichromate solution. The area stained with osmic acid-potassium dichromate

solution was determined by calculating the means of five triangular areas within the specimen whose angles are formed by the central vein and two portal canals.

Digital analysis of ultrasonograms

Digital analysis, using gray scale histogram analysis, of the ultrasonograms taken during ultrasonography was conducted as follows. The B-mode hepatic ultrasonograms were recorded using a still video record/player (Still Video 1000MH®, Fujix, Fuji Photo Film Co. Ltd., Tokyo, Japan). Area samples (1×1 cm) from different regions of the ultrasonograms of the hepatic parenchyma were taken at a depth of 1-9 cm from the hepatic surface (Fig. 1).

The echoes within the area samples were quantified as echo mean (Emean) values of the histogram of the echo amplitudes (Fig. 2) using a Region of Interest (ROI) program of an image analysis software (Image Command 4198, TV Image Processor 4100®, Excel Application Software, Japan Avionics Co., Tokyo, Japan). The x axis represents the different shades of the gray scale while the y axis represents the number of echoes. The Emean represents the average of the echo amplitudes within the area sample. The histogram had 252 shades in the gray scale of the image, from 0 (black) to 251 (white).

Comparison of the Emeans of normal liver and liver with various hepatocellular disorders was made and the difference was analyzed using Student's t test for comparison of samples with unequal sizes and different standard deviations (Snedecor and Cohran, 1980).

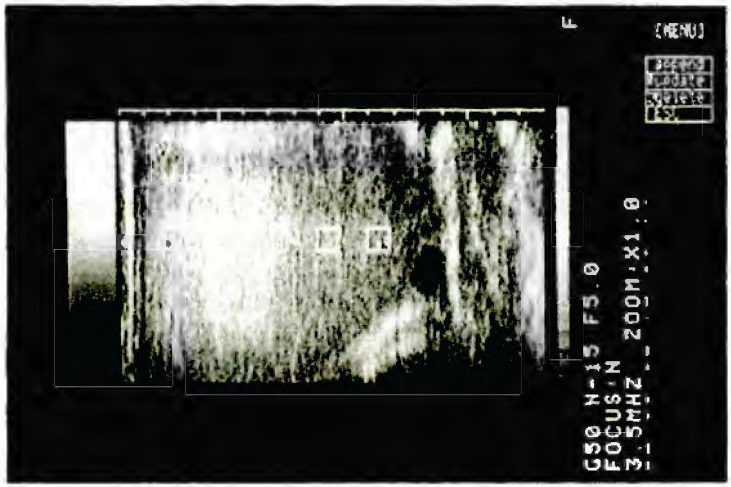


Figure 1. Area samples for hepatic histogram echo mean measurement.

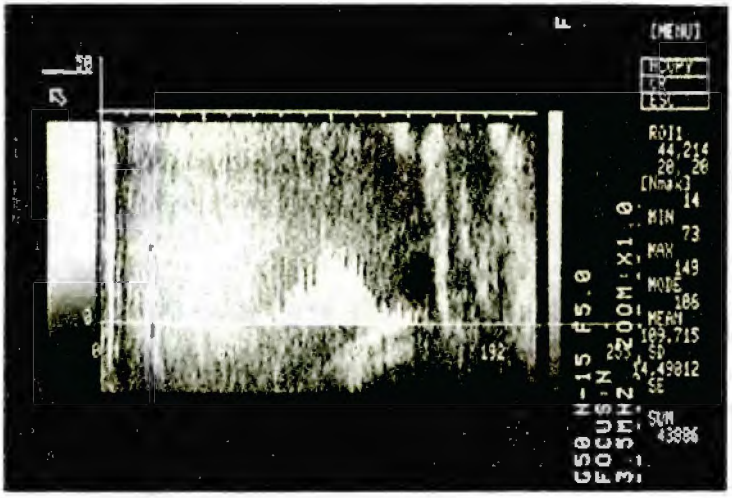


Figure 2. Echo histogram of hepatic ultrasonogram.

Diagnostic evaluation

The sensitivity, specificity, accuracy and positive and negative predictive values for the different diffuse hepatocellular disorders using ultrasonographic and digital analysis criteria were calculated according to the following formulas:

Calculation of diagnostic rates

Test	Histopathology	
	Positive	Negative
Positive	a	b
Negative	b	d

Sensitivity = $100 \times [\, a \div (a + c) \,]$

Specificity = $100 \times [\, d \div (b + d) \,]$

Accuracy = $100 \times [\, (a + d) \div (a + b + c + d) \,]$

Positive predictive value = $100 \times [\, a \div (a + b) \,]$

Negative predictive value = $100 \times [\, d \div (c + d) \,]$

Note: Test refers to the result of ultrasonographic findings or digital analysis while histopathology refers to the result of histopathological examination.

The test positive conditions for ultrasonographic findings were based on the following: a) for normal liver, ultrasonograms with no bright pattern, dark pattern, deep attenuation, vascular blurring and blurring of edges were considered test positive; b) for hydropic degeneration, ultrasonograms with dark pattern and blurring of edges were considered test positive; c) for fatty change, ultrasonograms with bright pattern, vascular blurring and deep attenuation were considered test positive; d) for hepatic dystrophy, ultrasonograms with bright pattern and blurring of edges were considered test positive; and e) for hepatic amyloidosis, ultrasonograms with bright pattern and blurring of edges were considered test positive.

The test positive conditions for digital analysis were based on the following: a) for normal liver, ultrasonograms with Emean values between 80-98, 75-93, 70-85, 63-78 and 55-70 at 1, 3, 5, 7 and 9 cm from the hepatic surface, respectively, were considered test positive; b) for hydropic degeneration, ultrasonograms with Emean values lower than 80 and 75 at 1 cm and 3 cm from the hepatic surface, respectively, were considered test positive; c) for fatty change, ultrasonograms with Emeans at 1 cm from the heaptic surface higher than 98 and Emeans lower than 63 and 55 at 7 cm from the hepatic surface, respectively, were considered test positive; d) for hepatic dystrophy, ultrasonograms with Emean at 3 cm from the hepatic surface greater than 93 were considered test positive; and e) for hepatic amyloidosis, ultrasonograms with Emean at 3 cm from the hepatic surface greater than 93 were considered test positive.

RESULTS

Of the 226 animals examined, 120 (53.1%) had a normal liver, 61 (27.0%) had hydropic degeneration of the liver, 41 (18.1%) had fatty change of the liver, 3 (1.3%) had hepatic dystrophy and 1 (0.5%) had hepatic amyloidosis. Hydropic degeneration was further classified into: a) mild, affecting only the centrilobular area (41 animals); b) moderate, affecting both centrilobular and midzonal regions (15 animals); and c) severe, affecting the whole hepatic lobule (5 animals). The fatty occupying rate (FOR) of the liver was classified as: a) mild, 1-15% FOR (21 animals); b) moderate, 15.1-30% FOR (10 animals); and c) severe, >30% FOR (10 animals).

The ultrasonogram of a normal liver shows slightly echogenic parenchyma with gradual attenuation of echoes. The parenchymal echoes are relatively uniform, the portal and hepatic vessels are visible and the hepatic edge is visible (Fig. 3).

In B-mode ultrasonograms of mild, moderate and severe hydropic degeneration, the parenchyma is more hypoechoic (dark pattern) and the edge is less distinct (blurring of edges) than that of the normal hepatic ultrasonogram (Fig. 4), especially in moderate and severe hydropic degeneration. In addition, the echoes in the amplitude mode (A-mode) are weaker compared to normal hepatic A-mode ultrasonogram.

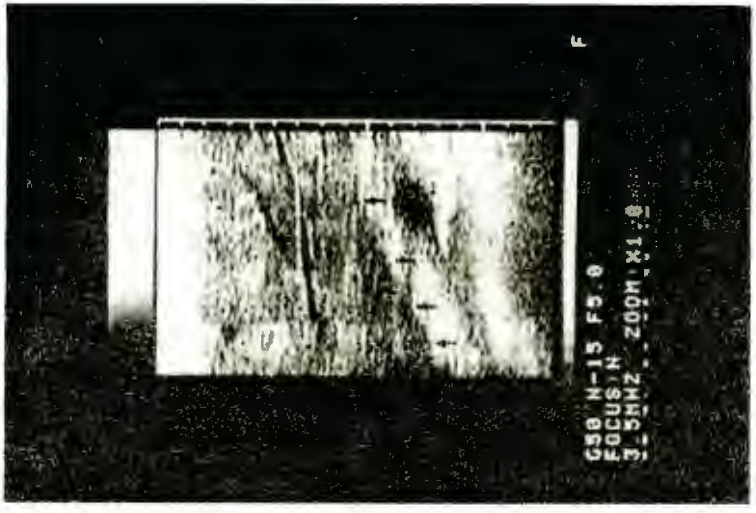


Figure 3. Ultrasonogram of a normal liver. PV: portal vein (with echogenic walls); HV: hepatic vein (without echogenic walls); black arrows show hepatic edge.

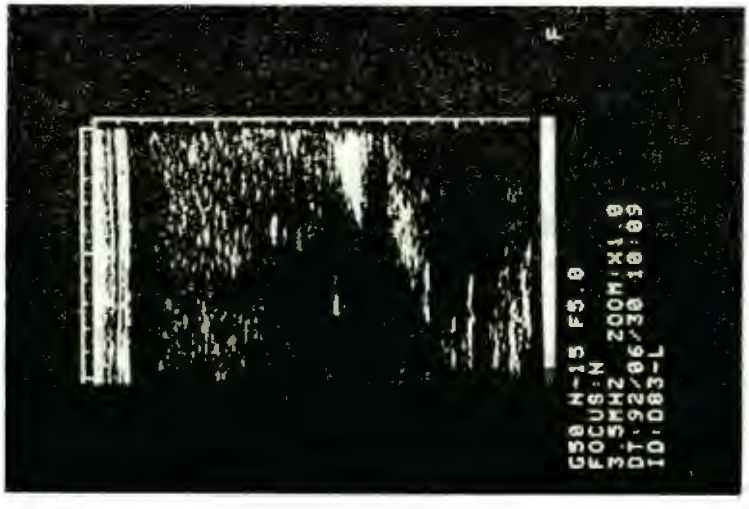


Figure 4. Ultrasonogram of severe hydropic degeneration of the liver.

Hyperechoic areas in the proximal region (bright pattern), hypoechoic areas in the distal region (deep attenuation), vascular blurring and blurring of edges can be seen in B-mode ultrasonograms of mild, moderate and severe fatty change of the liver (Fig. 5), especially in moderate and severe fatty change. In addition, the A-mode shows stronger echoes in the proximal region and more abrupt attenuation distally than in the normal hepatic A-mode ultrasonogram.

In B-mode ultrasonograms of hepatic amyloidosis and hepatic dystrophy (Figs. 6 and 7), the parenchyma of the liver in the ultrasonogram is more echogenic (bright pattern) than that of the normal liver and the parenchymal edges are barely visible (blurring of edges). The echoes in the A-mode, especially in the superficial portion, i.e. nearest the transducer-skin contact area, are stronger than the corresponding normal hepatic A-mode ultrasonogram.

Table 1 shows the echo mean (Emean) values of ultrasonograms of normal liver and diffuse hepatocellular disorders at different distances from the hepatic surface. The Emeans of normal liver decreased gradually from 1 cm to 9 cm from the hepatic surface, that of hydropic degeneration had a more rapid decline while that of fatty change decreased even more rapidly. The Emeans of hepatic dystrophy and hepatic amyloidosis both increased from 1 cm to 3 cm from the hepatic surface and decreased afterwards.

At 5 cm, 7 cm and 9 cm from the hepatic surface, the Emean values of hydropic degeneration were lower than the corresponding values in the normal liver. At 1 cm from the hepatic surface, the Emean value of fatty change was higher than that of normal liver. However, at 3 cm, 5 cm, 7 cm and 9 cm from the

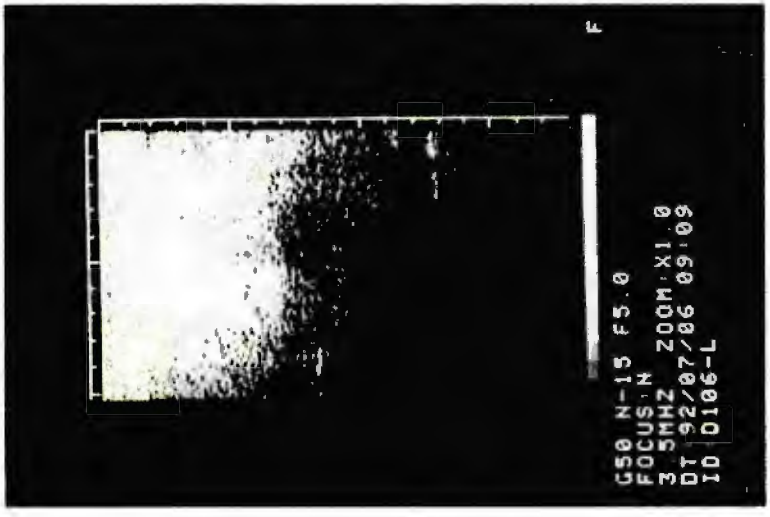


Figure 5. Ultrasonogram of severe fatty change if the liver.

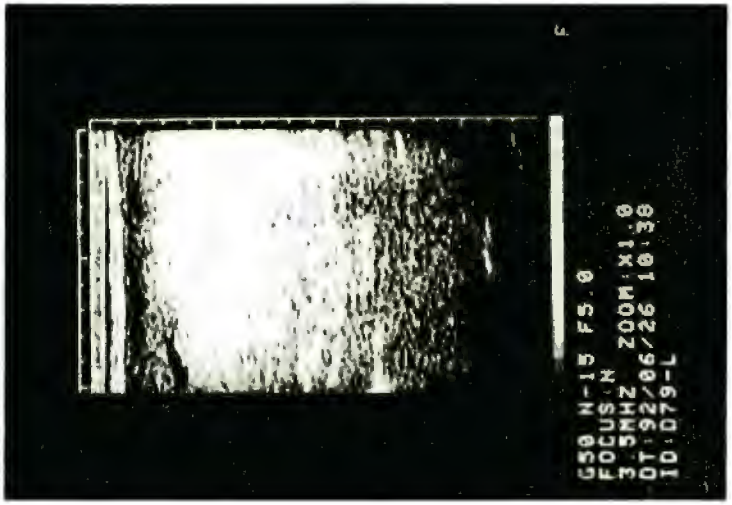


Figure 6. Ultrasonogram of hepatic dystrophy.

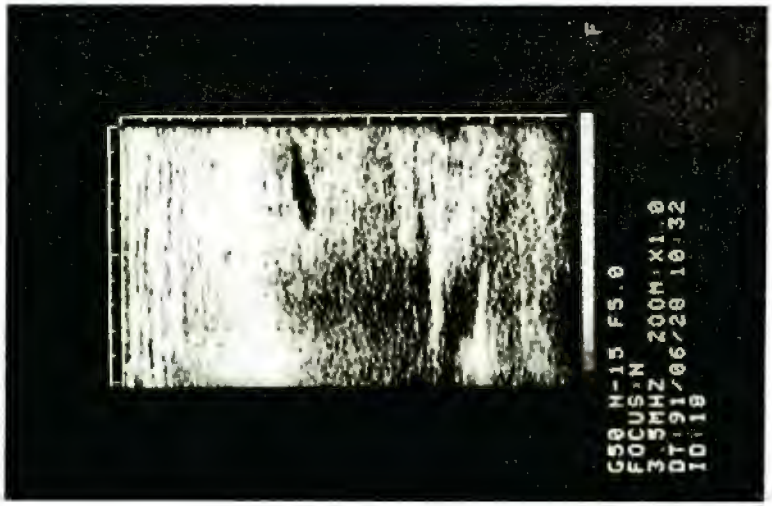


Figure 7. Ultrasonogram of hepatic amyloidosis.

Table I. Echo mean values obtained from digital analysis of hepatic ultrasonograms of animals with a normal liver and diffuse hepatocellular disorders.

Disorder	Distance from hepatic surface 1 cm	3 cm	5 cm	7 cm	9 cm
Normal liver	90.3	87.8	77.9	73.2	64.3
Hydropic degeneration	91.7	86.7	74.7	69.1	60.6
Fatty change	97.7	81.0	68.2	61.8	56.7
Hepatic dystrophy	82.5	92.5	88.0	76.0	69.0
Hepatic amyloidosis	95.0	109.0	90.0	76.0	67.0

hepatic surface, the Emean values of normal liver were higher than the corresponding values in fatty change. At 3 cm, 5 cm, 7 cm and 9 cm from the hepatic surface, Emean values of hepatic dystrophy and amyloidosis were higher than the corresponding values in the normal liver.

Table 2 shows the echo mean (Emean) values of ultrasonograms of different degrees of hydropic degeneration compared to normal liver. Emean values in hydropic degeneration decreased with increasing severity of degeneration. At all distances, Emean values of severe hydropic degeneration were lower than those of normal liver ($p<0.05$). At 7 cm and 9 cm from the hepatic surface, the Emean values of moderate hydropic degeneration were lower than those of normal liver ($p<0.05$).

Table 3 shows the echo mean (Emean) values of ultrasonograms of different degrees of fatty change compared to normal liver. Emean values increased with increasing severity of fatty change. Severe fatty change had the steepest decline from 1 cm to 9 cm from the hepatic surface. At 1 cm, the Emean value of severe fatty change was higher than that of normal liver ($p<0.05$). At 7 cm and 9 cm from the hepatic surface, the Emean values of both moderate fatty change and severe fatty change were lower than that of normal liver ($p<0.05$).

Table 4 shows the diagnostic accuracy rates for normal liver and diffuse hepatocellular disorders using ultrasonography and digital analysis. Ultrasonography is highly specific and relatively accurate for diagnosis of hydropic degeneration and fatty change of the liver. The accuracy rates increased with increasing severity of disorder. For hepatic dystrophy and hepatic amyloidosis, high negative predictive values were obtained. Diagnostic accuracy rates obtained through digital analysis for hydropic degeneration and fatty change were higher than those obtained through ultrasonography.

DISCUSSION

The contrast that is seen when echo beams pass through different layers of tissues and organs is one of the basic principles used in diagnostic ultrasound. The

Table 2. Echo mean values obtatined from digital analysis of hepatic ultrasonograms of animals with a normal liver and different degrees of hydropic degeneration.

	Distance from hepatic surface				
	1 cm	3 cm	5 cm	7 cm	9 cm
Normal liver	90.3	87.8	77.9	73.2	64.3
Hydropic degeneration					
Mild	93.0	89.0	76.0	70.0	61.0
Moderate	91.0	84.0	73.0	67.4*	60.0*
Severe	82.8*	75.6*	69.7*	66.8*	59.5*

*Significantly different from normal liver at $p<0.05$.

Table 3. Echo mean values obtained from digital analysis of hepatic ultrasonograms of animals with a normal liver and different degrees of fatty change.

	Distance from hepatic surface				
Disorder	1 cm	3 cm	5 cm	7 cm	9 cm
Normal liver	90.3	87.8	77.9	73.2	64.3
Fatty change					
Mild	91.5	81.4	72.8	69.1	61.3
Moderate	97.8	84.2	67.3	56.7*	53.6*
Severe	108.7*	77.2	60.5	54.8*	52.3*

*Significantly different from normal liver at $p<0.05$.

different shades of the gray-scale formed in the ultrasonogram can be attributed to the differences in acoustic impedance and absorption capacity between different tissues (Sanders and James, 1990). Basically, this contrast has been used to identify organs and structures within organs. It has also been used to identify changes within organs and changes in the relationship between organs. The increased presence of water, fat, amyloid, cells or connective tissue in the hepatic lobe causes changes in the parenchymal structure, giving rise to differing echo patterns.

In the evaluation of diffuse liver diseases in humans, different parameters have been used. Among them were parenchymal echogenicity, depth of beam penetration, visibility of hepatic portals veins, liver surface images (Arima *et al.*, 1990), hepatic micro- and macrotexture (Layer *et al.*, 1990), gall bladder wall

Table 4. Diagnostic accuracy rates for normal liver and diffuse hepatocellular disorders using ultrasonographic and digital analysis criteria.

Disorder	Sensitivity	Specificity	Accuracy	Positive Predictive value	Negative Predictive value
Ultrasonography					
Normal liver	53.0	71.6	61.9	66.7	58.6
Hydropic degeneration	41.0	81.2	70.4	44.6	78.8
Fatty change	61.0	83.8	79.6	45.5	90.6
Hepatic dystrophy	66.7	73.5	73.5	3.3	99.4
Hepatic amyloidosis	100.0	72.9	73.0	1.6	100.0
Digital analysis					
Normal liver	67.5	57.8	62.8	63.2	62.4
Hydropic degeneration	45.9	87.9	76.5	58.3	81.5
Fatty change	62.4	96.2	90.3	78.8	92.2
Hepatic dystrophy	66.7	72.2	72.1	3.1	99.4
Hepatic amyloidosis	100.0	72.0	72.1	1.6	100.0

echoes (Sato and Ogimoto, 1985), volume of the caudate lobe (Hess *et al.*, 1986), ultrasound velocity (Nishimura *et al.*, 1986), brightness scala values (Hoshino *et al.*, 1990), masking sign (Kojima *et al.*, 1989), stilette sign (Ingram and Joseph, 1989), fatty bandless sign (Mizuguchi *et al.*, 1986), coarsening (Hess *et al.*, 1986), homogeneity of hepatic echo patterns (Herdt *et al.*, 1983), elasticity, echo structure and sonic conductivity of the liver (Steinmaurer *et al.*, 1984).

In the normal hepatic ultrasonogram in dairy cattle, the parenchymal pattern consists of numerous weak echoes homogeneously distributed over the entire area of the liver (Braun, 1990). There is a gradual attenuation of the echo beam as it passes through the normal liver tissue. The hepatic and portal veins can be seen within the normal texture. In addition, the parenchymal edges are normally visible.

In animals with amyloidosis, the amyloid is deposited between the sinusoidal reticulum and hepatic cords (Kelly, 1985) of the peripheral parts of the lobules or intermediate zone (Cohrs, 1966). This deposition gives rise to increased echoes as seen in the ultrasonogram. Increased hepatic parenchymal echogenicity and small high echo spots scattered in the hepatic parenchyma were also observed in humans with amyloidosis (Otani *et al.*, 1986).

Two of the animals with hepatic dystrophy which had bright pattern had severe tissue necrosis, while the other one had only mild necrosis. The increased echogenicity seen in hepatic dystrophy, therefore, can be attributed to increased inflammatory cellular infiltration (Park *et al.*, 1981) and tissue necrosis (Sumino *et al.*, 1985). In this study, it was not possible to distinguish between amyloidosis and hepatic dystrophy by means of increased parenchymal echoes in the ultrasonogram alone.

The deposition of water in hydropic degeneration can be distinguished in the ultrasonogram. Tissues and organs with a physical density of 1.0 can be identified on gray-scale ultrasound scans by their specular and nonspecular echo patterns (Park *et al.*, 1981). The decreased echoes seen in hydropic degeneration can be attributed to the increased water content of the hepatocytes (Park *et al.*, 1981) since water has a lower absorption coefficient and higher acoustic impedance than normal hepatic tissue (Sanders and James, 1990). In animals where there is blurring of edges, the hepatic parenchyma tends to blend with the surrounding tissues so that the visceral surface of the liver cannot be accurately delineated.

In humans, bright pattern, deep attenuation, vascular blurring and blurring of edges were also observed in ultrasonograms of fatty change of the liver (Arima *et al.*, 1990). Increased parenchymal echogenicity in the proximal region in fatty change is caused by a higher absorption coefficient and lower acoustic impedance of fat as compared with normal liver tissue (Sanders and James, 1990). The increased echogenicity of the ultrasonogram seen in fatty change is due to the markedly echogenic mixture of fat and water in the hepatic parenchyma (Behan and Kazam, 1978). Due to immiscibility, multiple water-fat and fat-water interfaces form and cause increased echogenicity and attenuation of the ultrasound beam (Behan and Kazam, 1978).

Computer analysis of ultrasonographic echoes, including digital analysis, has been used in humans in the diagnosis of diffuse disorders of the liver. Computerized ultrasound examination yields for information from the ultrasound image than normal observation, which leads to increased diagnostic accuracy.

Digital analysis, in this study, was used to objectively quantify the echo amplitudes by calculating the echo mean of the histogram of the specific areas in the ultrasonogram, namely, the proximal hyperechogenicity or bright pattern, dark pattern and distal hypoechogenicity or deep attenuation observed in the hepatic ultrasonograms through ultrasonography. Since the degree of brightness of an ultrasonogram is subject to the observer's own evaluation, the use of digital analysis attempted to remove the observer's bias by presenting the results in terms of quantifiable figures. The high degree of accuracy obtained through digital analysis shows that this method can be more objective and accurate than ultrasonography alone.

Analysis of ultrasonograms, in this study, was able to identify different characteristics in the hepatocellular disorders, namely, hydropic degeneration, fatty change of the liver, hepatic dystrophy and amyloidosis. In humans, analysis of ultrasonograms have been used in the differential diagnosis of acute hepatitis (Schuster *et al.*, 1988), chronic hepatitis (Garra *et al.*, 1987), liver cirrhosis (Lerski *et al.*, 1982), fatty change (Lerski *et al.*, 1982), hepatic fibrosis (Lin *et al.*, 1987), hepatic tumors (Nicholas, 1979), chronic liver diseases (Naumov and Loukanov, 1987) and diffuse liver diseases (Cloostermans et al., 1987).

In this study, the higher Emean values at 1 cm from the hepatic surface in severe fatty change compared with normal liver represent the high echo ampli-

tudes or bright liver pattern. The lower Emeans at 5 cm, 7 cm and 9 cm seen in severe fatty change compared with normal liver, on the other hand, represent decreased penetration of echoes or deep attenuation. The lower Emeans at 3 cm, 5 cm, 7 cm and 9 cm from the hepatic surface seen in hydropic degeneration compared with normal liver, on the other hand, represent the dark pattern observed in ultrasonograms of hydropic degeneration.

REFERENCES

Arima K, Watanabe S, Hirabayashi S, Nakatsu T, Uchida N and Nishioka M. 1990. Sonographic diagnosis of diffuse chronic liver disease. Comparison with peritoneoscopic findings. *Proc. Jpn. Soc. Ultrasonic Med.* pp. 505-506.

Behan M and Kazam E. 1978. The echographic characteristics of fatty tissues and tumors. *Radiology* 129: 143-151.

Braun U. 1990. Ultrasonographic examination of the liver in cows. *Am. J. Vet. Res.* 51:1522-1526.

Cartee RE. 1981. Diagnostic real-time ultrasonography of the liver of the dog and cat. *J. Am. Anim. Hosp. Assoc.* 17: 731-737.

Cloostermans MJTM, Mol H, Verhoef WA, Thijssen JM and Kubat K. 1987. *In vitro* estimation of acoustic parameters of the liver and correlations with histology. *Ultrasound Med. Biol.* 12:39-51.

Cohrs P. 1966. *Textbook of the Special Pathological Anatomy of Domestic Animals.* Oxford: Pergamon Press.

Garra BS, Insana MF, Shawker TH and Russell MA. 1987. Quantitative estimation of liver attenuation and echogenicity: normal state versus diffuse liver disease. *Radiology* 162: 61-67.

Haberkorn VU, Zuna I, Zerban H, Layer G, Lorenz A, Van Kaick G and Rath U. 1989. Quantitative studies on the influence of connective tissue and fatty structures on the sonographic image of the liver. *Rofo Fortschr. Geb. Rontgenstr. Neuen Bildgeb. Verfahr.* 151: 439-442.

Herdt TH, Goeders L, Liesman JS and Emery RS. 1983. Test for estimation of bovine hepatic lipid content. *J. Am. Vet. Med. Assoc.* 182: 953-955.

Hess CF, Wolf A, Kolbel G and Kurtz B. 1986. Subjective evaluation and quantitative grey scale analysis in the sonographic diagnosis of diffuse abnormalities of the liver parenchyma. *Rofo Fortschr. Geb. Rontgenstr. Neuen Bildgeb. Verfhr.* 145: 140-144.

Hoshino K, Yokokawa T, Yamazaki Y, Kushida T, Ishiwata H, Ono Y, Arakawa Y and Matsuo Y. 1990. A study on quantity of ultrasonic images with power spectrum. *Proc. Jpn. Soc. Ultrasonic Med.* 539-540.

Ingram C and Joseph AEA. 1989. The stilette sign: the appearance of dilated bile ducts in the fatty liver. *Clin. Radiol.* 40: 257-258.

Kelly WR. 1985. The liver and biliary system. In: Jubb, KVF, Kennedy, PC and Palmer N. (eds.) *Pathology of Domestic Animals,* 3rd ed. Orland: Academic Press, Inc.

Kojima K, Seo H, Hino I, Kawasaki K, Satoh K, Tanabe M, Kawase Y and Mizukawa K. 1989. Ultrasonographic diagnosis of mild fatty infiltration of the liver with the difference between liver and kidney echo levels. *Nippon Acta Radiol.* 49: 153-162.

Lerski RA, Morley P, Barnette E, Mills PR, Watkinson G and MacSween RNM. 1982. Ultrasonic characterization of diffuse liver disease - the relative importance of frequency content in the A-scan signal. *Ultrasound Med. Biol.* 8:155-160.

Lin T, Ophir J and Potter G. 1987. Correlations of sound speed with tissue constituents in normal and diffuse liver disease. *Ultrason. Imag.* 9: 29-40.

Mizuguchi S, Hara T, Yoshimura K and Mori H. 1986. Ultrasonic diagnostic criteria of fatty liver in our hospital. *Proc. Jpn. Soc. Ultrasonic Med.* 557-558.

Naumov N and Loukanov L. 1987. The echographic histogram - its application in the diagnosis of chronic liver diseases. *Vutr. Boles.* 26: 50-55.

Nicholas D. 1979. Ultrasonic diffraction analysis in the investigation of liver disease. *Br. J. Radiol.* 52: 949-961.

Nishimura N, Akamatsu K, Miyauchi S and Ohta Y. 1986. A study on non-invasive quantitative measurement of the degree of fatty metamorphosis in the liver. *Proc. Jpn. Soc. Ultrasonic Med.* 67-68.

Otani T, Saito A, Akimoto S, Kurokawa K, Murata Y and Obata H. 1986. Ultrasonography of amyloidosis. *Proc. Jpn. Soc. Ultrasonic Med.* 563-564.

Park RD, Nyland TG, Lattimer JC, Miller CW and Lebel JL. 1981. B-mode gray-scale ultrasound: Imaging artifacts and interpretation. *Vet. Radiol.* 22:204-210.

Sanders RC and James AE. 1990. *The Principles and Practice of Ultrasonography in Obstetrics and Gynecology*, 2nd ed. New York: Appleton-Century-Croft.

Sato S and Ogimoto K. 1985. Distribution of serum antibodies to several rumen bacterial species in beef cattle with liver abscesses. *Jpn J. Zootech. Sci.* 56:87-91.

Schuster E, Knoflach P and Grabner G. 1988. Local texture analysis: an approach to differentiating liver tissue objectively. *J. Clin. Ultrasound* 16: 463-471.

Snedecor G W and Cochran WG. 1980. *Statistical Methods*, 7th ed. Ames: The Iowa State University Press.

Steinmaurer HJ, Jirak P, Walchshofer J and Clodi PH. 1984. Accuracy of sonography in the diagnosis of diffuse liver parenchymal diseases - comparison of sonography and liver histology. *Ultraschall Med.* 5: 98-103.

Sumino Y, Yoshida N, Ishii M, Yamamuro W, Ueno Y and Yamada H. 1985. Echographic diagnosis of liver diseases. *Proc. Jpn. Soc. Ultrasonic Med.* 45-46.