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Clinical Significance of Real-Time Two-Dimensional Shear Wave Elastography (SWE) in Assessing Liver Parenchymal Stiffness for Predicting the Severity of Non-Alcoholic Fatty Liver Disease (NAFLD)

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Abstract: Objective: To evaluate the value of real-time two-dimensional shear wave elastography (SWE) in predicting liver parenchymal stiffness in non-alcoholic fatty liver disease (NAFLD). Methods: A total of 200 NAFLD patients (70 in the mild group, 70 in the moderate group, and 60 in the severe group) and 60 healthy individuals (control group) who visited the hospital from December 2023 to December 2024 underwent real-time two-dimensional SWE examinations. Results: Except for high-density lipoprotein, comparisons of body mass index and biochemical indicators showed that the severe group > moderate group > mild group > control group, with $P < 0.05$. Comparisons of liver stiffness values also showed that the severe group > moderate group > mild group > control group, with $P < 0.05$. Pearson correlation analysis revealed a positive correlation between liver stiffness values and body mass index, triglycerides, total cholesterol, low-density lipoprotein, fasting blood glucose, and glycosylated hemoglobin. Analysis of the ROC curve indicated that the AUC, standard deviation, and P-value for liver stiffness values were 0.901, 0.025, and 0.01, respectively, suggesting that liver stiffness values can predict the severity of NAFLD. Conclusion: The real-time two-dimensional shear wave elastography (SWE) technique for diagnosing NAFLD can differentiate between NAFLD patients and healthy individuals, as well as determine liver parenchymal stiffness, thereby assisting physicians in quantifying the degree of fatty liver.

Keywords: NAFLD; Liver parenchymal stiffness; Real-time two-dimensional SWE technique; Predictive value

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1. Introduction

NAFLD is a common pathological type of chronic liver disease that progresses slowly. Due to the liver's robust metabolic capacity, the early detection rate in most patients is low after liver disease onset, leading to some cases of NAFLD progressing to cirrhosis or even liver failure by the time of detection. There are numerous clinical diagnostic schemes for NAFLD, with liver biopsy remaining the gold standard for grading. However, biopsy is an invasive procedure that carries risks of sampling errors and post-biopsy complications. Therefore, exploring efficient and non-invasive diagnostic techniques remains a clinical research focus [1]. The real-time two-dimensional SWE technique is a modern ultrasound technology that utilizes two-dimensional image-based elastography for quantitative detection of the region of interest and can obtain data such as liver stiffness indices, serving as a basis for physicians to qualitatively analyze NAFLD-related diseases. Based on this, this study used a sample of 200 NAFLD patients and 60 healthy individuals who sought medical attention from December 2023 to December 2024 to explore the diagnostic value of the real-time two-dimensional SWE technique.

2. Materials and methods

2.1. Materials

From December 2023 to December 2024, 200 NAFLD patients were enrolled, including 70 with mild NAFLD in the mild group, 70 with moderate NAFLD in the moderate group, and 60 with severe NAFLD in the severe group. Additionally, 60 healthy individuals were included in the control group during the same period. Baseline data comparisons among the four groups showed $P > 0.05$, as shown in **Table 1**.

Table 1. Baseline data analysis

Group	n	Gender (%)		Age (years)	
		Male	Female	Range	Mean ± SD
Mild Group	70	38 (54.29)	32 (45.71)	27-59	47.11 ± 1.11
Moderate Group	70	40 (57.14)	30 (42.86)	28-60	47.26 ± 1.18
Severe Group	60	35 (58.33)	25 (41.67)	27-60	47.67 ± 1.21
Control Group	60	34 (56.67)	26 (43.33)	25-60	47.81 ± 1.27

2.2. Inclusion and exclusion criteria

2.2.1. Inclusion criteria

(1) Patients with fatty liver disease meeting the NAFLD criteria outlined in the “Guidelines for the Prevention and Treatment of Non-Alcoholic Fatty Liver Disease” [2].
(2) Healthy individuals with no history of liver disease.
(3) Signed informed consent.
(4) CT scans of patients with fatty liver disease indicate low liver density.

2.2.2. Exclusion criteria

(1) Patients with fatty liver disease caused by other diseases.
(2) Individuals with a history of liver disease.
(3) Individuals with a history of long-term medication use or alcohol abuse.

2.3. Methodology

All subjects underwent scanning by two ultrasound physicians, with the convex array probe frequency of the ultrasound diagnostic instrument adjusted to 1–6 MHz. After fasting, subjects entered the examination room and assumed a supine position, with the right upper limb placed above the head. The right intercostal space was probed to obtain a sectional view of the right anterior lobe of the liver. Subjects were instructed to hold their breath and breathe as required, with the probing depth controlled at 3–5 cm. Conventional scanning was performed to obtain liver sonograms. The system was then switched to SWE mode, and the probe was translated without applying pressure. Scanning was completed using a segmented approach. After observing the elastogram maintaining a stable state for 3–5 seconds, the image was frozen. Subsequently, the average elasticity value of the right anterior lobe of the liver was measured. The sampling frame diameter was adjusted to 20 mm to obtain five consecutive data points, and the mean value was calculated. The severity of NAFLD was evaluated based on the following signs: (1) Scanning the near field of the liver region reveals diffuse enhanced signals, higher in intensity than those of the spleen and liver, with a decrease in signal intensity when scanning towards the far field of the liver region; (2) Scanning the intrahepatic ducts fails to yield clear structural images; (3) Scanning the liver margin reveals a rounded and blunt appearance, with mild to moderate enlargement of the liver volume; (4) Blood flow data acquisition shows no indication of colored blood flow or reduced blood flow signals within the liver on CDFI, while observing no abnormalities in the direction of intrahepatic blood vessels; (5) Scanning the capsule and transverse septa of the right lobe of the liver reveals blurred or incomplete echoes. When assessing the severity of NAFLD, all patients met criterion (1). For the mild group, one of criteria (2)–(4) was met; for the moderate group, two of criteria (2)–(4) were met; and for the severe group, two of criteria (2)–(4) were met, along with criterion (5).

2.4. Statistical research

Data processing was conducted using SPSS 23.0. Percentages were recorded, and count data were analyzed using the chi-square test (X^2 test). Mean ± standard deviation ($\bar{x} \pm s$) was recorded, and measurement data were analyzed using the t-test. Significant differences were observed, with $P < 0.05$.

3. Results

3.1. Body mass index and biochemical indicators

Except for high-density lipoprotein, when comparing body mass index and biochemical indicators, the severe group > moderate group > mild group > control group, with $P < 0.05$, as shown in **Table 2** and **Table 3**.

3.2. Comparison of liver stiffness values

When comparing liver stiffness values, the severe group (12.28 ± 2.11) kPa > moderate group (10.42 ± 1.42) kPa > mild group (8.22 ± 1.11) kPa > control group (6.21 ± 0.45) kPa, with $P < 0.05$.

3.3. Correlation between liver stiffness values and biochemical indicators

Pearson correlation analysis revealed a positive correlation between liver stiffness values and body mass index, triglycerides, total cholesterol, low-density lipoprotein, fasting blood glucose, and glycated hemoglobin, as shown in **Table 4**.

Table 2. Comparison of biochemical indicators between NAFLD patients and healthy individuals ($\bar{x} \pm s$)

Group	BMI (kg/m²)	Triglycerides (mmol/L)	Total Cholesterol (mmol/L)	LDL-C (mmol/L)
Mild Group (n=70)[1]	22.87 ± 1.65	1.62 ± 0.21	4.85 ± 0.25	2.61 ± 0.19
Moderate Group (n=70)[2]	25.11 ± 1.72	2.01 ± 0.32	5.19 ± 0.33	4.33 ± 0.28
Severe Group (n=60)[3]	27.21 ± 1.81	2.25 ± 0.43	5.95 ± 0.39	4.96 ± 0.32
Control Group (n=60)[4]	21.06 ± 1.11	1.41 ± 0.18	4.48 ± 0.21	1.11 ± 0.15
t/p (1 vs 2)	7.863/0.0000	8.525/0.0000	6.871/0.0000	42.528/0.0000
t/p (1 vs 3)	14.2957/0.0000	10.8463/0.0000	19.4065/0.0000	51.7354/0.0000
t/p (1 vs 4)	14.2957/0.0000	10.8463/0.0000	19.4065/0.0000	51.7354/0.0000
t/p (2 vs 3)	6.7741/0.0000	3.6403/0.0004	12.0361/0.0000	11.9722/0.0000
t/p (2 vs 4)	15.6535/0.0000	12.8777/0.0000	14.3553/0.0000	79.7769/0.0000
t/p (3 vs 4)	22.4362/0.0000	13.9581/0.0000	25.7065/0.0000	84.383/0.0000

Table 3. Comparison of biochemical indicators between NAFLD patients and healthy individuals ($\bar{x} \pm s$)

Group	HDL-C (mmol/L)	Fasting Blood Glucose (mmol/L)	HbA1c (%)
Mild group (n=70)[1]	1.10 ± 0.26	5.36 ± 0.59	5.64 ± 0.48
Moderate group (n=70)[2]	0.84 ± 0.21	6.11 ± 0.64	6.42 ± 0.57
Severe group (n=60)[3]	0.79 ± 0.11	7.26 ± 0.72	7.11 ± 0.64
Control group (n=60)[4]	1.62 ± 0.42	4.21 ± 0.44	4.22 ± 0.39
t/p (1 vs 2)	6.5087/0.0000	7.2088/0.0000	8.7575/0.0000
t/p (1 vs 3)	8.596/0.0000	16.5347/0.0000	14.9348/0.0000
t/p (1 vs 4)	8.6134/0.0000	12.4223/0.0000	18.3103/0.0000
t/p (2 vs 3)	1.6589/0.0996	9.6403/0.0000	6.5011/0.0000
t/p (2 vs 4)	13.6768/0.0000	19.3954/0.0000	25.2506/0.0000
t/p (3 vs 4)	14.8081/0.0000	27.9985/0.0000	29.869/0.0000

Table 4. Comparison of the correlation between liver stiffness values and biochemical indicators

Indicator	r	P
Body Mass Index (BMI)	0.269	0.001
Triglycerides	0.236	0.033
Total Cholesterol	0.236	0.031
LDL-C	0.261	0.002
Fasting Blood Glucose	0.219	0.038
HbA1c	0.217	0.048

3.4. ROC curve analysis of liver stiffness values for predicting NAFLD

The test variable was liver stiffness value. Using mild, moderate, and severe NAFLD patients as the standard, ROC curve analysis was conducted. It was found that the area under the curve (AUC), standard deviation, and *P*-value for liver stiffness values were 0.901, 0.025, and 0.01, respectively, with a 95% confidence interval of (0.861, 0.957). This suggests that liver stiffness values can predict the severity of NAFLD.

4. Discussion

NAFLD refers to hepatic steatosis not caused by alcohol or other clearly defined etiologies. Abnormalities in various aspects of fat metabolism can induce this condition, with common predisposing factors including genetic susceptibility and insulin resistance. As NAFLD progresses, it can lead to cirrhosis and even liver failure. Therefore, early diagnosis and clear grading are crucial for improving patient prognosis. Liver biopsy is often used clinically to diagnose NAFLD and is considered the gold standard for grading NAFLD.

However, this invasive procedure poses significant diagnostic challenges. With the advancement of imaging technology, ultrasound has gradually been employed in liver disease screening due to its advantages of being rapid, non-invasive, and repeatable. However, conventional ultrasound lacks quantitative indicators, making it difficult for physicians to quantitatively assess the disease and limiting its use as a basis for later-stage fatty liver treatment [3]. In recent years, real-time two-dimensional shear wave elastography (SWE) technology has gradually been applied in the diagnosis of NAFLD. It can obtain two-dimensional imaging without manual pressure application, enhancing the accuracy of liver tissue stiffness detection. Summarizing the advantages of real-time two-dimensional SWE technology in diagnosing NAFLD, it can compensate for the traumatic drawbacks of conventional liver biopsy. As a non-invasive examination, it does not result in infections, bleeding, pain, or other conditions post-examination, ensuring high safety.

During SWE scanning, the convex array probe frequency is adjusted to 1–6 MHz to generate transverse shear wave elasticity images without the need for contrast agent-assisted imaging. This approach avoids the impact of invasive procedures such as biopsies on the body, making it more tolerable for NAFLD patients and suitable for long-term dynamic monitoring of NAFLD. SWE technology provides quantitative feedback on liver stiffness, serving as a basis for physician grading. During scanning, it measures the stiffness values of liver tissue in the target area, enabling quantitative feedback on the absolute stiffness of the liver. The stiffness values are positively correlated with the degree of fatty liver and the extent of local tissue fibrosis. After SWE technology screens for NAFLD, patients can undergo symptomatic drug interventions and lifestyle modifications, leading to a decrease in liver stiffness values.

Therefore, regular follow-up with real-time two-dimensional SWE can be conducted to assess the control effect of NAFLD and adjust treatment plans accordingly. Real-time two-dimensional shear wave elastography (SWE) technology can acquire data on the liver capsule, morphology, and size, while simultaneously measuring liver tissue stiffness values. This facilitates a comprehensive assessment of liver pathology by physicians. For instance, after some patients with non-alcoholic fatty liver disease (NAFLD) progress to cirrhosis, they may simultaneously exhibit signs such as reduced liver diameter, irregular liver margins, and increased liver tissue stiffness. Real-time two-dimensional SWE scanning can avoid non-target regional structures, including the gallbladder and major blood vessels, resulting in fewer measurement errors and the ability to acquire multiple data points simultaneously, thereby enhancing the accuracy of diagnostic results.

Furthermore, in comparison to conventional liver ultrasound examinations, which can only identify liver echo attenuation signals and indirectly assist physicians in diagnosing NAFLD, conventional ultrasound technology has low sensitivity in diagnosing mild NAFLD and struggles to quantitatively assess changes in the patient's condition, leading to missed diagnoses. In contrast, real-time two-dimensional SWE technology has a screening accuracy comparable to liver biopsy results and can assist physicians in identifying early-stage NAFLD. When conducting SWE technology examinations, it is only required that the examinee fasts for 2–3 hours in advance; there is no need to discontinue regular medication or fast for extended periods. During the acquisition of two-dimensional ultrasound data, the physician scans the right intercostal space with the probe, facilitating the avoidance of bile ducts and blood vessels under ultrasound guidance. Consequently, the patient only needs to hold their breath for 3–5 seconds to obtain accurate stiffness measurement data, thereby shortening the waiting time for patients. After the examination, the results are displayed as a color-coded elastogram, providing an intuitive representation of the liver stiffness distribution in the examinee. This technology can automatically calculate and store multiple data points, facilitating subsequent repeated comparative analysis of changes in the patient's condition [4].

However, to ensure the accuracy of real-time two-dimensional SWE technology scanning, it is necessary to guide patients in preparing for the examination, such as fasting as instructed by the physician to avoid the influence of food intake on liver blood flow before the examination, which could alter liver stiffness measurement data. If scanning is performed without fasting, gastrointestinal motility and gallbladder contraction can impede the propagation of shear wave signals, thereby affecting the accuracy of the measurement data. During SWE technology scanning, patients should hold their breath as instructed by the physician. It is recommended that patients take shallow breaths and then hold their breath to avoid motion artifacts caused by respiration. Abnormal respiratory movements in patients can lead to liver displacement, even altering the path of shear wave signals and reducing detection sensitivity.

During the scanning process, patients are required to maintain a supine position. If necessary, they should raise their right upper limb to fully expose the intercostal space, facilitating the physician's movement of the probe and avoiding interference with shear wave signals from structures such as lung tissue and ribs, thereby enhancing the quality of SWE imaging. During scanning, attention should also be paid to the placement and depth adjustment of the probe. It is recommended to place the probe perpendicular to the chest wall to avoid interference with imaging from structures such as bile ducts, blood vessels, and ribs.

The scanning depth should be controlled between 3–5 cm to fully display the liver parenchyma and avoid interference with shear wave signals from superficial tissues like the abdominal wall and deep tissues like the kidneys, ensuring optimal imaging quality as much as possible. Before and after real-time two-dimensional SWE scanning, the surface of the probe should be cleaned to prevent cross-infection events [5]. Furthermore, this study chose real-time two-dimensional SWE technology for diagnosing NAFLD due to its cost-effectiveness, with examination costs lower than those of CT and MRI, making it suitable for dynamic monitoring of NAFLD.

Based on the data analysis in this study, except for high-density lipoprotein, comparisons of body mass index and biochemical indicators showed that the severe group > the moderate group > the mild group > the control group, with $P < 0.05$. The reason for this is that NAFLD patients all exhibit metabolic disorders, and the severity of NAFLD is positively correlated with the degree of metabolic disorder. Dyslipidemia, abnormal blood glucose levels, and obesity can accelerate the progression of NAFLD. Therefore, individuals with higher body mass index, blood lipids, and blood glucose levels tend to have more severe NAFLD.

Another set of data indicates that comparisons of liver stiffness index showed that the severe group > the moderate group > the mild group > the control group, with $P < 0.05$. The reason for this is that after the onset of NAFLD, the disease gradually worsens under the influence of multiple factors such as the progression of liver tissue fibrosis, liver inflammation, and fatty degeneration. For example, inflammatory factors infiltrate the liver tissue, exacerbating the degree of liver cell fibrosis and liver cell damage. Fatty degeneration can intensify inflammatory responses, while the progression of liver tissue fibrosis inhibits the repair of damaged liver cells. This vicious cycle can further exacerbate the severity of fatty liver. Therefore, patients with severe NAFLD have higher liver stiffness indices compared to those with moderate and mild NAFLD [6].

The final set of data indicates that Pearson correlation analysis revealed a positive correlation between liver stiffness values and body mass index, triglycerides, total cholesterol, low-density lipoprotein, fasting blood glucose, and glycated hemoglobin. Furthermore, analysis of the ROC curve demonstrated that the AUC for liver stiffness values was 0.901, suggesting that liver stiffness values can accurately predict the severity of NAFLD and serve as a basis for physicians to determine appropriate treatment methods for NAFLD. Additionally, there are differences in liver stiffness values among patients with varying degrees of NAFLD. Therefore, analyzing the condition of NAFLD patients based on liver stiffness values during ultrasound examinations offers the advantages of speed and accuracy, and can avoid the traumatic issue of liver tissue biopsy [7]. However, this study included a relatively small number of NAFLD patients and healthy controls and did not conduct a multicenter analysis of the diagnostic efficacy of two-dimensional shear wave elastography (2D-SWE) technology. Future studies should include a larger number of NAFLD patients to further explore the predictive value of 2D-SWE technology.

5. Conclusion

In summary, 2D-SWE technology can differentiate between NAFLD patients and healthy individuals. By measuring liver stiffness indices, it can assist physicians in grading NAFLD and holds value for widespread application.

Disclosure statement

The authors declare no conflict of interest.

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