Association Between Ultrasound-Derived Fat Fraction (UDFF) Values and Metabolic Syndrome Laboratory Parameters in Metabolic Dysfunction-Associated Steatotic Liver Disease (MASLD)

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Abstract

Background:
Metabolic Dysfunction-Associated Steatotic Liver Disease (MASLD), formerly known as Non-Alcoholic Fatty Liver Disease (NAFLD), is highly prevalent worldwide and is strongly associated with metabolic syndrome and its related conditions such as diabetes mellitus and hypertension. Without early detection and intervention, hepatic steatosis can progress to hepatic inflammation, fibrosis, cirrhosis, and even hepatocellular carcinoma (HCC). This study aims to evaluate the relationship between ultrasound-derived fat fraction (UDFF) values and laboratory parameters of metabolic syndrome in MASLD, particularly liver enzymes, lipid profile, and glycemic profile, as well as to determine the optimal UDFF cut-off value for detecting metabolic syndrome risk in Indonesian patients.

Methods:
A cross-sectional study was conducted on 96 patients who underwent UDFF and laboratory assessments including liver enzymes (SGOT/AST, SGPT/ALT), lipid profile (total cholesterol, HDL, LDL, triglycerides), and glycemic profile (HbA1c, fasting blood glucose). Data analysis included bivariate-multivariate correlation and ROC analysis.

Result:
The distribution of UDFF (%) was as follows: normal ≤6% (27.1%; n=26), mild >6–15% (37.5%; n=36), moderate >15–25% (21.9%; n=21), and severe >25% (13.5%; n=13). UDFF showed a moderate positive correlation with SGPT (ρ=0.370; $p<0.01$) and triglycerides (ρ=0.380; $p<0.01$), and a weak negative correlation with HDL (ρ=−0.221; $p<0.05$). A UDFF threshold of 14% was able to predict abnormal SGPT levels and elevated triglycerides.

Conclusions:
UDFF shows a significant correlation with laboratory parameters of metabolic syndrome in MASLD, confirming its potential as an accessible, effective, efficient, non-radiative, and non-invasive imaging modality. These findings support the central role of radiology in the early detection and therapeutic monitoring of MASLD and metabolic syndrome, as well as in preventing disease progression from hepatic steatosis to inflammation, fibrosis, cirrhosis, and hepatocellular carcinoma (HCC). Large-scale multicenter validation is required to optimize these findings.

Introduction

Metabolic Dysfunction–Associated Steatotic Liver Disease (MASLD), previously known as non-alcoholic fatty liver disease (NAFLD), is the most prevalent liver disease worldwide and is closely associated with metabolic syndrome and its related conditions, such as diabetes mellitus and hypertension.[1-5] Without early detection and intervention,

hepatic steatosis may progress to hepatic inflammation, fibrosis, cirrhosis, and ultimately hepatocellular carcinoma.[3]

Conventionally, liver biopsy is considered the gold standard for diagnosing and staging the spectrum of fatty liver disease. However, its invasive nature and the relatively high risk of post-procedural complications make it less ideal as a primary modality for long-term therapeutic monitoring.[6] Among non-invasive imaging modalities, Magnetic Resonance Imaging-Proton Density Fat Fraction (MRI–PDFF) is currently regarded as the reference standard, with diagnostic accuracy approaching that of liver biopsy. Nevertheless, MRI–PDFF is limited by restricted accessibility, prolonged examination time, and high cost.[7]

Ultrasound-Derived Fat Fraction (UDFF) is a radiologic modality that utilizes ultrasound technology to provide quantitative assessment of hepatic fat content, with a detection threshold of less than 5%, and has demonstrated a strong correlation with MRI– PDFF as the non-invasive gold standard.[6-9] Owing to its ability to generate objective quantitative results, UDFF has the potential to serve as an effective, efficient, radiation- free, and non-invasive tool for screening and monitoring MASLD.[6]

Despite these advantages, the relationship between UDFF values and metabolic parameters, such as liver enzymes (AST/SGOT, ALT/SGPT), lipid profile (total cholesterol, HDL, LDL, triglycerides), and glycemic profile (fasting blood glucose, HbA1c) remains to be fully elucidated. Several studies have reported correlations between UDFF and metabolic variables including BMI, triglyceride levels, HDL, and liver enzymes.[10-11] However, comprehensive data evaluating the association between UDFF and metabolic syndrome parameters in the Indonesian population remain limited. This study aims to assess the relationship between UDFF values and laboratory parameters of metabolic syndrome in MASLD, particularly liver enzymes (AST, ALT), lipid profile (total cholesterol, HDL, LDL, triglycerides), and glycemic profile (HbA1c, fasting plasma glucose).

Material And Methods

This study is a retrospective cross-sectional study analyzing Ultrasound-Derived Fat Fraction (UDFF) values obtained using Siemens Acuson Sequoia ultrasound and laboratory parameters of metabolic syndrome, particularly liver enzymes (AST/SGOT, ALT/SGPT), lipid profile (total cholesterol, HDL, LDL, triglycerides), and glycemic profile (HbA1c, fasting plasma glucose), collected from the PACS system and medical records of Siloam Kebon Jeruk Hospital during the period 2023–2025.

Sample collection was conducted using consecutive sampling, with a minimum required sample size of 85 subjects based on sample size calculation, following approval from the Ethics Committee of the Faculty of Medicine, Pelita Harapan University (No. 269/K-LKJ/ETIK/IX/2025) and Siloam Kebon Jeruk Hospital (No. 922/SHKJ-DIR/IX/2025). A total of 96 samples were collected and analyzed using bivariate analysis (Spearman rank correlation), multivariate analysis (Kruskal–Wallis test), and AUC–ROC analysis using SPSS software.

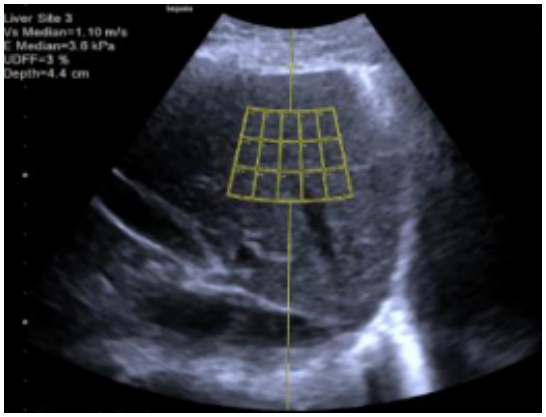

Figure 1. Ultrasound-derived fat fraction (UDFF) examination acquired using the Siemens Acuson Sequoia ultrasound system, displayed via the PACS system.

Result

This study included 131 patients who underwent UDFF examination at the Medical Check-Up Unit of Siloam Kebon Jeruk Hospital. After the screening process, a total of 96 samples were included in the final analysis.

Subject Characteristic

Table 1. Association between age, gender, and ultrasound-derived fat fraction (UDFF).

Age	(n)	Mean	UDFF (%)
21 - 30	12	38.58	Chi-Square = 5.392
31 – 40	19	43.42	Df = 4
41 – 50	14	61.82	Asymp. Sig. = .249
51 – 60	27	48.93	*Kruskal-Wallis
>60	24	49.23	
Total	96		

Gender	N	Mean	UDFF (%)	
Male	63	50.39	Mann-Whitney U	920.500
Female	33	44.89	Wilcoxon W	1481.500
Total	96		Z	-.919
			Asymp. Sig. (2-tailed)	.358

There was no significant association between the degree of UDFF values and age or sex.

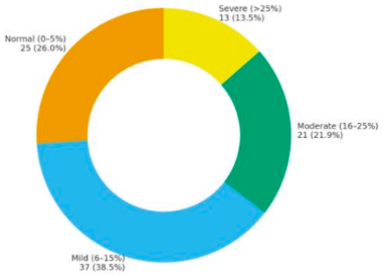

Figure 2. Distribution of study subjects by UDFF category.

The adjacent table shows the distribution of samples across UDFF categories: normal (n = 25; 26.0%), mild (n = 37; 38.5%), moderate (n = 21; 21.9%), and severe (n = 13; 13.5%)

Test of normality

Based on the Kolmogorov–Smirnov and Shapiro–Wilk normality tests, UDFF values and all related variables were found to be non-normally distributed, including total cholesterol and HDL. Therefore, Spearman's rank correlation was used for bivariate analysis, and the Kruskal–Wallis test was applied for multivariate analysis.

Correlation Between UDFF and Study Variables

Table 2. Spearman Bivariate Analysis

Test Variable (Spearman)	Correlation Coefficient (ρ)	Significance (2-tailed) (p)	Sample size (n)
SGOT	0.141	0.170	96
SGPT	**0.370**	**0.000**	96
Total Cholesterol	0.105	0.309	96
HDL	**-0.221**	**0.030**	96
LDL	0.107	0.298	96
Triglyceride	**0.380**	**0.000**	96
GDP	0.108	0.295	96
HbA1C	0.115	0.403	55

UDFF demonstrated a moderate positive correlation with ALT (SGPT) (p = 0.370; p < 0.01) and triglycerides (p = 0.380; p < 0.01), as well as a weak negative correlation with HDL (p = -0.221; p < 0.05).

Table 3. Kruskal-Wallis Multivariate Analysis.

	SGOT	SGPT	T. Kol	HDL	LDL	TG	HbA1C	GDP
Chi Square	3.215	13.476	3.303	8.121	2.475	19.887	1.204	1.534
Df	3	3	3	3	3	3	3	3
Asymp. Sig,	.360	**.004**	.347	**.044**	.480	**.000**	.752	.674

a. Kruskal Wallis Test
b. Grouping Variable: Grade UDFF

There was a significant association between UDFF groups (normal, mild, moderate, and severe) and ALT (SGPT) (p < 0.05), triglycerides (p < 0.01), and HDL (p < 0.05).

Tabel 4. Analisa ROC cut-off value.

Marker	AUC	UDFF *cut-off*	Sensitivity, Specificity	PPV NPV
SGPT > 35 U/L	0.678	14%	71.8 % 62.1 %	58.3% 75%
TG > 150 mg/dL	0.600	14%	59.1 % 60.8 %	31% 83.3%

A UDFF cutoff value of 14% predicted abnormal ALT (SGPT) with an AUC of 0.678, sensitivity of 71.8%, specificity of 62.1%, PPV of 58.3%, and NPV of 75.0%, and elevated triglyceride levels with an AUC of 0.600, sensitivity of 59.1%, specificity of 60.8%, PPV of 31.0%, and NPV of 83.3%.

Discussion

This study demonstrates that Ultrasound-Derived Fat Fraction (UDFF) values are significantly associated with laboratory parameters of metabolic syndrome (triglycerides and HDL) as well as with a marker of hepatic injury (ALT/SGPT). These findings are consistent with the pathophysiology of fatty liver disease, in which excessive triglyceride accumulation arising from broader systemic metabolic dysfunction leads to increased hepatocellular injury and intrahepatic and extrahepatic metabolic dysregulation.[10-14]

Bivariate analysis using Spearman's correlation revealed a moderate positive correlation between UDFF and ALT (SGPT) (ρ = 0.370; p < 0.01) and triglyceride levels (ρ = 0.380; p < 0.01), as well as a weak negative correlation between UDFF and HDL (ρ = −0.221; p < 0.05). Kruskal–Wallis multivariate analysis further demonstrated significant differences in ALT (p = 0.004), triglycerides (p < 0.001), and HDL (p = 0.044) across UDFF severity groups (normal, mild, moderate, and severe), reinforcing the association

between the degree of hepatic steatosis and metabolic disturbance.

In this study, a UDFF cutoff value > 14% served as a predictor of abnormal ALT and elevated triglyceride levels. Based on the significant parameters identified, an initial scoring system model (UDFF-RMS) was developed to enable rapid, non-invasive risk stratification of metabolic syndrome in MASLD, facilitating early intervention using UDFF measurements combined with routine laboratory parameters (ALT, triglycerides, and HDL).

UDFF and Liver Enzymes (ALT/SGPT) as Indicators of Hepatic Injury

Physiologically, ALT (SGPT) is the enzyme most specific for hepatocellular injury, as it is predominantly localized in the cytoplasm of hepatocytes, in contrast to AST (SGOT), which is also present in skeletal muscle and cardiac tissue. The results of this study demonstrate a positive association between UDFF and ALT, supporting the hypothesis that hepatic fat accumulation induces oxidative stress, subclinical inflammation, and mitochondrial dysfunction, ultimately leading to the release of ALT into the circulation.[10-15]

These findings are consistent with previous literature identifying ALT as a sensitive marker of fatty liver severity, particularly in the early to intermediate stages of the disease.[10-15] In contrast, no significant correlation was observed between UDFF and AST, which may be explained by the lower hepatic specificity of AST and the potential influence of extrahepatic factors such as physical activity or muscle and cardiac disorders.[16-18]

UDFF and Lipid Profile (Triglycerides and HDL) as Indicators of Metabolic Syndrome

The positive correlation between UDFF and triglyceride levels reflects a direct relationship between hepatic fat accumulation and systemic dyslipidemia. Elevated circulating triglycerides are indicative of insulin resistance and increased hepatic production of very low-density lipoprotein (VLDL), which represent key pathogenic mechanisms underlying both hepatic steatosis and metabolic syndrome.[19-23]

Conversely, the negative association between UDFF and HDL suggests that greater severity of hepatic steatosis is associated with lower levels of hepatoprotective HDL. This reduction in HDL is linked to increased activity of cholesteryl ester transfer protein (CETP), which accelerates HDL degradation and contributes to further deterioration of the lipid profile. The absence of a significant association between UDFF and total cholesterol or LDL may be attributed to the heterogeneous nature of total cholesterol, which comprises multiple fractions with differing biological effects, and to the fact that LDL primarily reflects average cholesterol content per particle, rather than atherogenic lipoprotein activity such as apolipoprotein B (ApoB)[24-27] .

UDFF and Glycemic Profile

Analysis of the glycemic profile demonstrated no significant association between UDFF and either fasting plasma glucose or HbA1c levels. This finding is consistent with the pathophysiology of early-stage hepatic steatosis, in which the body is still able to maintain normoglycemia through compensatory hyperinsulinemia.[1-5]

Consequently, increases in UDFF may occur earlier than detectable alterations in glycemic parameters. In addition, HbA1c data were limited in this study (n = 55 of 96 samples), which may have reduced the statistical power of the analysis. Future studies are warranted to include potential confounding factors, such as medical history, physical activity, stress levels, and medication use, to further elucidate the relationship between UDFF and glycemic control.

Limitations of the Study and Recommendations for Future Research

The limitations of this study include its cross-sectional design, which permits the identification of associations but precludes the establishment of causal relationships, a relatively limited sample size, and incomplete HbA1c data. In addition, several potential confounding factors, including medical history, medication use, alcohol

consumption, and lifestyle factors, could not be fully controlled. The proposed risk scoring model remains preliminary and requires further validation through studies involving larger sample sizes and more diverse populations.

Future research should employ prospective study designs, incorporate additional metabolic variables such as visceral fat, HOMA-IR, and fibrosis markers (e.g., elastography).

Conclusion

Ultrasound-Derived Fat Fraction (UDFF) demonstrated significant correlations with laboratory parameters of metabolic syndrome in MASLD, underscoring its potential as an accessible, effective, efficient, radiation-free, and non-invasive imaging modality. These findings support the central role of radiology in the early detection and therapeutic monitoring of MASLD and metabolic syndrome, as well as in preventing disease progression from hepatic steatosis to inflammation, fibrosis, cirrhosis, and hepatocellular carcinoma (HCC).

Large-scale multicenter validation is required to optimize its performance and to enhance the generalizability of these findings.

Acknowledgment

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