



Association between Non-Alcoholic Fatty Liver Disease and Carotid Intima-Media Thickness: A Clinical Investigation

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Abstract

Background: This study investigates the relationship between Non-Alcoholic Fatty Liver Disease (NAFLD) and Carotid Intima-Media Thickness (CIMT), a key indicator of cardiovascular risk. It aims to provide insights for developing strategies to address the growing impact of NAFLD on cardiovascular health.

Methods: This cross-sectional study included 138 participants, 69 with non-alcoholic fatty liver disease and 69 healthy controls aged 18–50. Data were collected from medical records, diagnostic tests, and liver and carotid ultrasounds. Statistical analysis was conducted using SPSS 27, employing the Mann-Whitney U test and Generalized Estimating Equation (GEE) model, with a significance level of $p < 0.05$.

Results: The average age was 36.35 yr, mostly 30–39. The NAFLD patients were older, with higher overweight (20.6%) and smoking (47%) rates. They also had significantly higher carotid intima-media thickness.

Conclusion: This study highlights a significant link between NAFLD and CIMT. Patients with NAFLD had higher CIMT values than healthy controls. Factors like Body Mass Index (BMI), overweight status, smoking, and age also showed significant correlations with CIMT. These findings underscore the need for early detection and targeted interventions to reduce cardiovascular risks in NAFLD patients.

Keywords: Atherosclerosis, CIMT, Metabolic syndrome, NAFLD

Introduction

Cardiovascular diseases, with atherosclerosis as a key cause, are leading global causes of death, and increased arterial wall thickness, measured by carotid ultrasound, is an indicator of subclinical atherosclerosis (1). This study examines the link between Non-Alcoholic Fatty Liver Disease (NAFLD) and Carotid Intima-Media Thickness (CIMT), considering factors like diabetes and hypertension (2). NAFLD has become a growing concern, with its prevalence rising from 2.9 in 2011 to 21.5% in 2013, likely due to lifestyle changes and improved diagnostic tools (3,4). Risk factors for NAFLD include obesity, insulin resistance, and metabolic syndrome (5-7). NAFLD is associated with obesity, cardiovascular disease, and type 2 diabetes, and its progression can lead to severe liver damage, such as cirrhosis and hepatocellular carcinoma (8,9). Ultrasound is a reliable, non-invasive screening tool for NAFLD.

Recent studies suggest a connection between NAFLD and atherosclerosis, though results are inconsistent (10-12). Given the increasing prevalence of fatty liver and its impact on cardiovascular health, this study examines the independent relationship between fatty liver severity and CIMT (12-14). Cardiovascular diseases are recognized as one of the leading causes of death globally, with atherosclerosis being one of the main causes.

Increased CIMT is an early sign of atherosclerosis and can serve as a predictive marker for assessing cardiovascular disease risk. Given the high prevalence of NAFLD and its association with metabolic disorders and atherosclerosis, understanding the impact of NAFLD on carotid thickness could play a significant role in the prevention and treatment of cardiovascular diseases. Since there have been limited independent studies on the relationship between NAFLD and CIMT in Guilan province and many other regions, this research can serve as an important step in examining this connection and providing preventive and therapeutic strategies to reduce the prevalence and impact of cardiovascular diseases caused by NAFLD.

Materials and Methods

Study design and setting

This was a cross-sectional, comparative analytical

study conducted at the Razi Educational and Medical Center, Rasht, Iran, in 2025.

Participants and sampling

A total of 138 participants were included, consisting of 69 patients diagnosed with NAFLD and 69 age- and sex-matched healthy controls. The patients were recruited consecutively among those referred to the hospital's ultrasound unit. The sample size was determined with 95% confidence and 90% statistical power, based on the previous studies.

Inclusion and exclusion criteria

Inclusion criteria: Adults aged 18–60 yr with and without NAFLD confirmed by ultrasound, no history of significant alcohol consumption (less than 20 g/day).

Exclusion criteria: Patients with chronic liver disease of other etiology, diabetes mellitus, hypertension, cardiovascular disease, dyslipidemia, malignancy, cerebrovascular accidents, or other major comorbidities.

Data collection and measurements

Demographic data (age, sex), Body Mass Index (BMI) (calculated as weight in kg divided by height in m^2), and smoking history were recorded. Liver enzymes (ALT and AST) were measured from recent laboratory tests. NAFLD diagnosis and grading were performed using abdominal ultrasound by an experienced radiologist (curvilinear probe). Grading was based on standard echogenicity criteria:

Grade 1: Mild diffuse increase in hepatic echogenicity, diaphragm and intrahepatic vessel borders visible.

Grade 2: Moderate increase, with slight impairment of visualization.

Grade 3: Marked increase, poor or no visualization of vessel borders and diaphragm.

CIMT was measured bilaterally on the common carotid arteries near the bifurcation using a linear probe (e.g., Mindray device). The distance between the intima-lumen and media-adventitia interfaces was recorded. Measurements were performed by a single trained radiologist blinded to patient status.

Statistical analysis

Statistical analyses were performed using SPSS version 27. Continuous variables were tested for

normality with Kolmogorov–Smirnov and Shapiro–Wilk tests. Since CIMT did not follow a normal distribution, the Mann–Whitney U test was used to compare CIMT between the groups. Categorical variables were compared using Chi-square tests. Spearman’s correlation coefficient assessed associations between liver enzymes and CIMT. To adjust for potential confounding factors (age, BMI, gender, smoking status), a GEE model was applied. Statistical significance was set at $p < 0.05$.

Ethical consideration

The study was approved by the Ethics Committee of Guilan University of Medical Sciences (IR.GUMS.REC.1403.200). Written informed consent was obtained from all the participants. Data were anonymized and kept confidential.

Results

This chapter presents the results from the analysis of 138 participants (69 with NAFLD and 69 healthy controls) to assess the association between NAFLD and CIMT at Razi Educational and Medical Center, Rasht, Iran, in 2025.

The demographic analysis revealed that the mean age of the participants was 36.35 yr ($SD=9.02$). The NAFLD group was significantly older and had a higher average BMI than the healthy controls (both $p=0.001$) (Table 1). However, multivariate analysis using GEE model showed that the association between NAFLD and increased CIMT remained statistically significant even after adjusting for age and BMI, indicating that these variables did not confound the primary relationship.

Gender distribution did not differ significantly

Table 1. Distribution of non-alcoholic fatty liver disease (NAFLD) by age, sex, BMI, and smoking history

Variable	NAFLD (+) N	%	NAFLD (-) N	%	Total N	%	p-value
Age group							
20-29 <i>yr</i>	8	11.6%	25	36.2%	33	23.9%	<0.001
30-39 <i>yr</i>	27	39.1%	31	44.9%	58	42.0%	
40-49 <i>yr</i>	23	33.3%	13	18.8%	36	26.1%	
50-60 <i>yr</i>	11	15.9%	0	0.0%	11	8.0%	
Mean age (<i>yr</i>)	40.22	-	32.48	-	36.35	-	<0.001
SD	8.80	-	7.47	-	9.02	-	
Minimum age	26	-	20	-	20	-	
Maximum age	58	-	49	-	58	-	
Sex							
Male	35	50.7%	33	47.8%	68	49.3%	0.733
Female	34	49.3%	36	52.2%	70	50.7%	
Body Mass Index (BMI)							
Under weight	0	0.0%	0	0.0%	0	0.0%	<0.001
Normal weight	54	79.4%	67	97.1%	121	88.3%	
Overweight	14	20.6%	2	2.9%	16	11.7%	
Obese	0	0.0%	0	0.0%	0	0.0%	
Smoking history							
Yes	30	43.5%	35	50.7%	65	47.1%	0.394
No	39	56.5%	34	49.3%	73	52.9%	

between the two groups ($p=0.733$). Smoking history was more common in the NAFLD group (47%) but did not differ significantly ($p=0.394$). Carotid thickness showed a nonnormal distribution ($p<0.001$), leading to the use of non-parametric tests for further analysis (Table 2). A significant increase in carotid thickness was observed in the NAFLD group compared to the healthy controls ($p<0.001$) (Table 3). Carotid

thickness was consistently higher in the NAFLD group across all the age and gender subgroups, with significant differences observed in most categories ($p<0.05$) (Table 4). Significant differences in carotid thickness were found between smokers and non-smokers in both groups ($p=0.004$ and $p=0.001$, respectively), as well as based on BMI. Notably, the NAFLD group with a normal BMI indicated a

Table 2. Tests of normality for carotid thickness and liver enzymes in the two study groups

Study group/variable	Kolmogorov-smirnov statistic	df	Sig.	Shapiro-wilk statistic	df	Sig.
Case - right carotid thickness (mm)	0.196	70	0.000	0.873	70	0.000
Case - left carotid thickness (mm)	0.509	70	0.000	0.119	70	0.000
Case - ALT enzyme	0.166	70	0.000	0.869	70	0.000
Case - AST enzyme	0.173	70	0.000	0.855	70	0.000
Control - right carotid thickness (mm)	0.094	69	0.200*	0.958	69	0.021
Control - left carotid thickness (mm)	0.096	69	0.195	0.967	69	0.063
Control - ALT enzyme	0.13	69	0.005	0.827	69	0.000
Control - AST enzyme	0.18	69	0.000	0.817	69	0.000

Kolmogorov-Smirnov and Shapiro-Wilk tests for normality. * This is a lower bound of the true significance.

a. Lilliefors Significance Correction.

Table 3. Comparison of right and left carotid thickness between the two study groups

		Right carotid thickness (mm)	Left carotid thickness (mm)	p-value
Non-alcoholic fatty liver disease	Count	69	69	0.670
	Mean	0.65	0.65	
	Standard deviation	0.15	0.18	
	Median	0.58	0.60	
	Percentile 25	0.52	0.54	
	Percentile 75	0.79	0.78	
	Count	69	69	0.062
	Mean	0.51	0.52	
	Standard deviation	0.80	0.07	
	Median	0.52	0.52	
	Percentile 25	0.45	0.46	
	Percentile 75	0.55	0.58	
	p-value	$p<0.001$	$p<0.001$	

Mann-Whitney U test.

Table 4. Comparison of right and left carotid thickness between the two study groups by age group and gender

		Right carotid thickness (mm)		p-value	Left carotid thickness (mm)		p-value	
		Non-alcoholic fatty liver disease			Non-alcoholic fatty liver disease			
Age group (yrs)	20-29		Yes	No	0.108	Yes	No	0.194
		Count	8	25		8	25	
		Mean	0.51	0.47		0.51	0.48	
		Standard deviation	0.05	0.04		0.07	0.05	
		Median	0.49	0.47		0.52	0.46	
		Percentile 25	0.48	0.43		0.47	0.45	
		Percentile 75	0.55	0.51		0.55	0.50	
	30-39	Count	27	31	0.019	27	31	0.034
		Mean	0.59	0.52		0.60	0.53	
		Standard deviation	0.11	0.07		0.11	0.06	
		Median	0.54	0.52		0.57	0.53	
		Percentile 25	0.51	0.47		0.52	0.50	
		Percentile 75	0.64	0.55		0.64	0.58	
	40 and up	Count	34	13	0.019	34	13	0.014
		Mean	0.74	0.60		0.72	0.5	
		Standard deviation	0.20	0.08		0.15	0.07	
		Median	0.73	0.62		0.77	0.60	
		Percentile 25	0.56	0.56		0.59	0.55	
		Percentile 75	0.90	0.64		0.85	0.65	
Gender	Male	Count	35	33	0.004	35	33	0.001
		Mean	0.67	0.54		0.66	0.56	
		Standard deviation	0.18	0.07		0.14	0.06	
		Median	0.60	0.54		0.63	0.56	
		Percentile 25	0.53	0.51		0.55	0.50	
		Percentile 75	0.81	0.61		0.80	0.60	
	Female	Count	34	36	-	34	36	0.001
		Mean	0.63	0.49		0.63	0.49	
		Standard deviation	0.18	0.07		0.16	0.07	
		Median	0.55	0.48		0.57	0.48	
		Percentile 25	0.51	0.43		0.50	0.45	
		Percentile 75	0.73	0.52		0.78	0.54	

Table 5. Comparison of right and left carotid thickness between the two study groups according to smoking and body mass index

		Right carotid thickness (mm)		p-value	Left carotid thickness (mm)		p-value		
		Non-alcoholic fatty liver disease			Non-alcoholic fatty liver disease				
Smoking history	Yes		Yes	No	0.004		Yes	No	0.003
		Count	30	35		Count	30	35	
		Mean	0.68	0.54		Mean	0.66	0.55	
		Standard deviation	0.20	0.08		Standard deviation	0.15	0.07	
		Median	0.61	0.54		Median	0.62	0.56	
		Percentile 25	0.53	0.48		Percentile 25	0.55	0.50	
		Percentile 75	0.81	0.61		Percentile 75	0.78	0.60	
	No	Count	39	34	0.001	Count	39	34	0.001
		Mean	0.63	0.49		Mean	0.64	0.50	
		Standard deviation	0.16	0.07		Standard deviation	0.16	0.07	
		Median	0.55	0.49		Median	0.58	0.49	
		Percentile 25	0.51	0.43		Percentile 25	0.51	0.45	
		Percentile 75	0.79	0.52		Percentile 75	0.80	0.55	
	Body mass index	Normal weight	Count	55	67	0.001	Count	55	67
Mean			0.63	0.51	Mean		0.62	0.52	
Standard deviation			0.16	0.07	Standard deviation		0.14	0.07	
Median			0.57	0.51	Median		0.59	0.51	
Percentile 25			0.51	0.45	Percentile 25		0.53	0.46	
Percentile 75			0.72	0.55	Percentile 75		0.74	0.57	
Over weight		Count	14	2	0.750	Count	14	2	0.689
		Mean	0.75	0.67		Mean	0.74	0.66	
		Standard deviation	0.22	0.04		Standard deviation	0.18	0.01	
		Median	0.82	0.67		Median	0.80	0.66	
		Percentile 25	0.53	0.64		Percentile 25	0.57	0.65	
		Percentile 75	0.84	0.70		Percentile 75	0.90	0.67	

significant increase in carotid thickness ($p < 0.001$), whereas there were no significant differences in overweight or obese individuals (Table 5). A strong positive correlation was found between ALT, AST, and carotid thickness in the entire sample ($p < 0.001$), indicating a significant relationship between liver enzyme levels and carotid thickening (Table 6). The

same correlation was evident in both NAFLD and healthy control groups, with statistically significant findings for both right and left carotid thickness (Table 7). The GEE analysis confirmed that NAFLD had a significant effect on carotid thickness, even after adjusting for confounding factors (Tables 8 and 9).

Table 6. Correlation between right and left carotid thickness and liver enzymes ALT, AST in all the samples

		Correlations		
		Liver enzyme ALT	Liver enzyme AST	Right carotid thickness (mm)
Spearman's rho	Liver enzyme ALT	rsp	1.000	-
		p-value	<0.001	-
		N	139	-
	Liver enzyme AST	rsp	0.672	0.670
		p-value	<0.001	-
		N	139	-
	Right carotid thickness (mm)	rsp	0.672	0.670
		p-value	<0.001	<0.001
		N	139	139
	Left carotid thickness (mm)	rsp	0.699	0.698
		p-value	<0.001	<0.001
		N	139	139

"rsp" = Spearman's rho.

Importantly, the GEE analysis confirmed that NAFLD had a significant and independent effect on increased CIMT after adjusting for potential confounders such as age, BMI, gender, and smoking status (Tables 8 and 9). While age contributed marginally and significantly to carotid thickness, BMI, particularly in the overweight category, demonstrated no statistically significant independent effect. These findings underscore the role of NAFLD as an independent predictor of subclinical atherosclerosis, regardless of age or body mass index.

Discussion

This study was a cross-sectional, comparative analysis conducted to explore the relationship between NAFLD and CIMT in patients visiting the Razi Hospital in Rasht, Iran, in 2025. A total of 138 samples were used, including 69 patients with NAFLD and 69 healthy controls. The mean age of the participants was 36.35 yr with a standard deviation of 9.02 yr. The youngest participant was 20 yr old, and the oldest was 58. The majority of the participants were in the 30–39 age range. The NAFLD group had a higher mean age compared to the control group,

with approximately equal gender distribution (50% male, 50% female). The NAFLD group had a higher percentage of overweight individuals (20.6 compared to 2.9%) and 47% of the patients were smokers. There was a statistically significant difference in CIMT between the two groups, with the NAFLD group exhibiting higher median and mean CIMT values compared to the healthy controls.

The median and mean CIMT values in the NAFLD group were higher across all the age and gender subgroups, and this difference was statistically significant in most subgroups. A significant relationship between CIMT and smoking status was observed, with smokers showing greater CIMT values than non-smokers in both groups. Regarding BMI, a significant difference was found only in those with a normal BMI, while in overweight individuals, although CIMT was higher in the NAFLD group, the difference was not statistically significant. Spearman's correlation coefficient revealed a significant positive correlation between liver enzymes (ALT and AST) and CIMT, both in the right and left carotid arteries. This suggests a strong positive relationship between liver dysfunction and arterial thickness, supporting

Table 7. Correlation between right and left carotid thickness and liver enzymes ALT, AST, separated into two groups

		Correlations			
		Liver enzyme ALT	Liver enzyme AST	Right carotid thickness (mm)	Left carotid thickness (mm)
Spearman's rho	Case group	rsp	1.000	-	-
		p-value	<0.001	-	-
		N	70	-	-
		rsp	0.962	1.000	-
		p-value	<0.001	-	-
		N	70	70	-
		rsp	0.511	0.512	1.000
		p-value	<0.001	<0.001	-
		N	70	70	70
		rsp	1.000	-	-
		p-value	<0.001	<0.001	<0.001
		N	69	-	-
	Control group	rsp	1.000	-	-
		p-value	<0.001	-	-
		N	69	-	-
		rsp	0.959	1.000	-
		p-value	<0.001	<0.001	-
		N	69	69	-
		rsp	0.708	0.694	1.000
		p-value	<0.001	<0.001	-
		N	69	69	69
		rsp	0.753	0.741	0.843
		p-value	<0.001	<0.001	<0.001
		N	69	69	69

Table 8. Results of GEE analysis of the correlation between carotid thickness and non-alcoholic fatty liver disease, controlling for the effects of individual intervening variables

Parameter estimates							
Parameter	B	Std. error	95% wald confidence interval		Hypothesis test		
			Lower	Upper	Wald chi-square	df	p-value
Intercept	0.315	0.381	0.240	0.390	348.68	1	<0.001
Nonalcoholic fatty liver disease	0.062	0.140	0.035	0.090	19.980	1	<0.001
No non-alcoholic fatty liver	a0	-	-	-	-	-	-
Normal body mass index	0.072	0.212	-0.114	-0.031	11.647	1	<0.001
Body mass index with overweight	a0	-	-	-	-	-	-
Male	0.15	0.135	-0.012	0.041	1.176	1	<0.001
Female	a0	-	-	-	-	-	-
Smoking	0.035	0.135	0.009	0.062	0.866	1	<0.001
No smoking	a0	-	-	-	-	-	-
Age	0.008	0.008	0.006	0.009	89.780	1	<0.001

B: Coefficient (Beta), a0: Reference Category, df: Degrees of Freedom.

Table 9. Comparison of right and left carotid Intima-media thickness based on fatty liver grade (with post hoc analysis)

Fatty liver grade	N	Right carotid thickness (mm) Mean $\pm$ SD	Left carotid thickness (mm) Mean $\pm$ SD	Post hoc comparison (Tukey)
No fatty liver	-	0.5300 $\pm$ 0.4851	0.5294 $\pm$ 0.4671	1<2, 1<3
Mild/Moderate NAFLD	-	0.6707 $\pm$ 0.1743	0.6726 $\pm$ 0.1494	2<3
Severe NAFLD	-	0.8156 $\pm$ 0.2014	0.7867 $\pm$ 0.1368	-
Total	-	0.6531 $\pm$ 0.1771	0.6504 $\pm$ 0.1511	-
p-value	-	<0.001 (significant)	<0.001 (significant)	-

the systemic effects of NAFLD on vascular health. Multivariate analysis, controlling for confounders like smoking and BMI revealed that NAFLD was still significantly associated with increased CIMT. Normal BMI was significantly related to CIMT, whereas smoking and age also played an important role in influencing CIMT.

These results align with previous studies such as Kumari *et al*, who found a significant correlation between CIMT and NAFLD, especially in patients with higher degrees of NAFLD (15). Similarly, Farcas *et al* demonstrated a link between CIMT and different obesity phenotypes, including those with NAFLD (16). Additionally, the study by Mohammadzadeh *et al* revealed that NAFLD was an independent risk factor for increased CIMT, even after adjusting for other cardiovascular risk factors (17). The results of current study are in line with the results of Khan *et al* who conducted a study aimed at determining the relationship between increased carotid intima-media thickness and non-alcoholic fatty liver disease. This study was conducted with a case-control design in the outpatient department of diagnostic radiology of a hospital in Islamabad and included all the patients referred to the radiology department. Ultrasound examination was performed to diagnose the presence of NAFLD.

CIMT was measured in both groups of the patients with and without NAFLD. The increase in CIMT in patients and controls was 29 (18.7%) and 16 (10.3%), respectively, and their difference was statistically significant [(1.854-3.0377) 2.00, and OR=0.05> p-value]. Similar to the results, the researchers

concluded that CIMT in the NAFLD group was significantly increased compared to the control groups (18).

Conclusion

This study shows that the right and left carotid intima-media thickness is significantly higher in patients with NAFLD compared to healthy individuals. The mean and median CIMT values were greater in the NAFLD group across all age and gender subgroups. Additionally, BMI, overweight status, smoking, and age were found to correlate significantly with increased CIMT in both groups.

Ethical approval

This study was conducted by the ethical principles outlined in the Declaration of Helsinki. The Ethics Committee of Guilan University of Medical Sciences (IR.GUMS.REC.1403.200) reviewed and approved the research protocol and procedures involving human participants. These ethical guidelines protect the study participants' rights, welfare, and well-being.

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Conflict of Interest

There is no conflict of interest to declare.

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