Original Article

Analysis of Quality Intima-Media Thickness and Quantitative Artery Stiffness technologies on non-alcoholic fatty liver disease: a study on carotid artery structure, elasticity, and influential factors in patients

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Background: In recent years, there have been numerous studies using Quality Intima-Media Thickness (QIMT) and Quantitative Arterial Stiffness (QAS) technology to evaluate various related factors and disease-induced changes in carotid artery (CA) elasticity. However, there is still a lack of research on the relationship between non-alcoholic fatty liver disease (NAFLD) and various indicators related to the CA. This study aimed to investigate the clinical significance of using QIMT and QAS techniques for comprehensive evaluation of CA intima-media thickness (IMT) and elasticity changes in NAFLD patients, and to analyze various factors influencing these variables.

Methods: In this cross-sectional study, a total of 196 healthy adults and 285 NAFLD patients were selected from June 2021 and October 2021 in the First Affiliated Hospital of Zhejiang University School of Medicine. Body mass index (BMI), blood pressure, and triglyceride levels were collected. CA IMT and pulse wave velocity (PWV) were measured using QIMT and QAS techniques. Multiple linear regression analysis was employed to explore the relationship between parameters measured using QIMT and QAS techniques and NAFLD, while controlling for covariates, to assess the measurement effects of QIMT and QAS techniques on arterial structure and elasticity in NAFLD patients.

Results: A total of 233 males and 248 females were included in this study, with 178 males (62.46%) and 107 females (37.54%) being diagnosed with NAFLD. Gender, age, systolic blood pressure (SBP), and uric acid (UA) all are related to CA IMT (estimated value −0.031 to 0.008, $P<0.0001$–$P=0.0450$). The presence of NAFLD was not significantly related to IMT, but primarily influenced vascular elasticity indicators α, β, PWV, augmentation index (Aix), distensibility coefficient (DC), and compliance coefficient (CC). Age, SBP, diastolic blood pressure (DBP), high-density lipoprotein (HDL), and UA were all related to vascular elasticity coefficient β (estimated value −0.05 to 1.03, $P<0.0001$–$P=0.0451$); SBP and UA had a relationship with PWV (estimated value −0.001 to 0.405, $P<0.0001$–$P=0.0027$); gender, age, SBP, DBP, and UA all influenced Aix (estimated value −0.17 to 0.65, $P<0.0001$–$P=0.0072$).

Conclusions: Ultrasound radiofrequency (RF) signal QIMT and QAS techniques can reflect changes in CA structure and elasticity function in NAFLD patients, which can be more widely applied and promoted in the changes of CA structure and elastic function in NAFLD patients.

Keywords: Non-alcoholic fatty liver disease (NAFLD); Quality Intima-Media Thickness technique (QIMT technique); Quantitative Arterial Stiffness technique (QAS technique); intima-media thickness (IMT); carotid artery (CA)

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Introduction

Non-alcoholic fatty liver disease (NAFLD) is a metabolic stress-related liver injury closely associated with insulin resistance and genetic susceptibility. The spectrum of the disease includes non-alcoholic fatty liver, non-alcoholic steatohepatitis (NASH), cirrhosis, and hepatocellular carcinoma (1,2), which has been officially renamed as metabolic dysfunction-associated steatotic liver disease (MASLD). MASLD, defined as the presence of hepatic steatosis in conjunction with 1 cardiometabolic risk factor (CMRF) and no other discernible cause, alcohol-associated/related liver disease (ALD), and an overlap of the 2, termed metabolically-associated alcoholic liver disease (MetALD), comprise the most common causes of steatotic liver disease (SLD) (3). The term "non-alcoholic" refers to the absence of a history of excessive alcohol consumption (men <30 g/day of ethanol equivalent, women <20 g/day) and other specific causes that can lead to fatty liver (4). The prevalence of NAFLD is rapidly increasing compared to the rising prevalence of obesity and type 2 diabetes (5,6). Numerous studies have indicated that NAFLD has significant implications for cardiovascular health. The cardiovascular complications associated with NAFLD are the leading cause of mortality in patients with this condition (7-10). Closely monitoring cardiovascular changes in NAFLD patients is of great clinical significance (11,12). Previous research has indicated that NAFLD affects the mechanism of carotid atherosclerosis as follows: NAFLD is considered a hepatic manifestation of metabolic syndrome, and it is closely associated with metabolic syndrome (13,14), NAFLD and metabolic syndrome are believed to have similar effects on arteries, accelerating the development of atherosclerosis through factors such as inflammation, increased oxidative stress, imbalances in adipokines, hypercoagulability, abnormal lipid metabolism, and dysregulated hepatokines (15-21). Stefan *et al.* reviewed the pathogenesis of the 3 types of NAFLD and suggested that NAFLD can be considered both a driver and a result of the prevalence of diabetes (5). Indeed, studies have found a significant association between NAFLD and carotid artery (CA) stenosis in the Chinese population (22). Therefore, early evaluation of changes in the intima-media thickness (IMT) and elasticity function of carotid arteries is particularly important for the early diagnosis and treatment of cardiovascular complications in NAFLD patients (23).

Due to its convenience, CA routine ultrasound examination is one of the most commonly used methods in clinical practice to indicate the occurrence and development of cardiovascular diseases. Measurement of IMT in the CA is considered a powerful predictor of future vascular events and can be used as an alternative marker for atherosclerosis (24-26). With the rapid development of ultrasound elastography technology, arterial elasticity assessment has been gradually introduced into routine clinical practice. The combined application of arterial elasticity assessment and IMT measurement is considered a powerful tool for diagnosing cardiovascular diseases (27). Indeed, both of these examination methods are manually performed by medical experts, and subjectivity can greatly affect the results. The outcomes are heavily constrained by intra-observer variability and inter-observer variability, as well as equipment and data sample differences (28-30).

Ultrasound radiofrequency (RF) technology is a new method for assessing the elasticity of CAs, which includes the Quality Intima-Media Thickness (QIMT) analysis based on ultrasound RF signal and Quantitative Arterial Stiffness (QAS) technology. These are collectively referred to as "QIMT and QAS technology" and are gradually becoming important means of evaluating vascular function and morphology. The QIMT technology measures the inner diameter and IMT of blood vessels using RF signals, with an accuracy reaching micrometers. The QAS technology quantitatively evaluates vessel wall elasticity based on RF signals, serving as a real-time detection tool for changes in vessel wall diameter (or elasticity) following blood pressure fluctuations induced by cardiac pumping. Through high frame rates and RF signal resolution, the QAS technology measures parameters such as pulse wave velocity (PWV) and vascular dilation, and combines locally recorded blood pressure [systolic (SBP) or diastolic (DBP)] for analysis to obtain multiple indices of vascular function, including the distensibility coefficient (DC), compliance coefficient (CC), stiffness parameter α, stiffness parameter β, and augmentation index (Aix). The QIMT and QAS technology automatically tracks and measures arterial wall, analyzes the related data, and acquires relevant data, thus eliminating the influence of human factors. Compared to conventional ultrasound examinations, this method provides more accurate, objective, and comprehensive measurements, and is non-invasive, convenient, and exhibits good repeatability, offering significant advantages for the early diagnosis and treatment of arterial sclerosis (31-35).

The QIMT and QAS technologies can provide a large amount of objective quantitative data for assessing the structure and function of the CA. In recent years, there have been numerous studies using QIMT and QAS technology to evaluate various related factors and disease-induced changes in CA elasticity. However, there is still a lack of research on the relationship between NAFLD and various indicators related to the CA. Therefore, this study aimed to use QIMT and QAS technology to quantitatively assess the structure and elastic function of the CA in NAFLD patients, and compare them with a healthy control group. The objective was to observe changes in the vascular structure and function of the CA in NAFLD patients and investigate whether NAFLD has a relationship with various quantitative parameters of the CA. This research aimed to provide early data for NAFLD patients, enabling the early detection of changes in the CA and the implementation of effective intervention measures. We present this article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-24-1179/rc).

Methods

Participants

A total of 196 healthy Han Chinese adults aged 19–79 years and 285 patients with NAFLD (liver imaging by ultrasound showed characteristic features of diffuse fatty liver; see Figure S1) who visited the First Affiliated Hospital of Zhejiang University School of Medicine between June 2021 and October 2021 were prospectively selected as participants. The examinations were conducted using the Esaote My lab9 color Doppler ultrasound diagnostic system (Esaote, Genoa, Italy) with an L4–15 probe. The instrument is equipped with QIMT and QAS technologies for measuring the IMT and elastic function (including Aix, PWV, α, β, DC, and CC) of the CA (specific examination steps are described in the Appendix 1). Details about the maker of the instrument (QIMT and QAS), its model, and associated built-in parameters can been seen in Figures S2-S6. Before the examination, all patients underwent liver and kidney function tests, electrolyte analysis, and lipid and blood glucose tests. Blood pressure measurements were taken for all patients before the examination. Other recorded variables included patient's name, gender, date of birth, examination date, telephone number, height, weight, blood pressure, fasting blood glucose (FBG), total cholesterol (TC), triglycerides (TG), low-density lipoprotein (LDL), high-density lipoprotein (HDL), uric acid (UA), medical history, smoking history (number of cigarettes per day and number of years), alcohol consumption history (number of beer bottles and measure of white wine and red wine per year), and other variables. All patients signed informed consent forms. The inclusion and exclusion criteria for patients are provided in the Appendix 1. The IMT thickness and vascular elasticity of the CA were primarily examined by a deputy chief physician with over 10 years of experience in vascular ultrasound examinations. Additionally, two attending physicians with over 7 years of experience in vascular ultrasound examinations participated and underwent strict professional training in QIMT and QAS technologies. A data quality control officer was assigned to review the data collected and exclude cases with inadequate quality from the database. Extreme outliers, either significantly large or small values, were flagged for review. Such outliers were reevaluated by the site's principal investigator or the designated physician-in-charge to ascertain data validity and to rule out data entry errors.

The research was conducted in accordance with good clinical practice guidelines and the Helsinki Declaration (as revised in 2013). The protocol and amendments have been approved by the Ethics Committee of Lishui People's Hospital (No. 2024-007) and the Ethics Committee of The First Affiliated Hospital, Zhejiang University School of Medicine [2021 ITT Fast Track Review No. (806)]. Informed consent was provided by all individual participants.

Statistical analysis

The statistical software R 4.2.1 (The R Foundation for Statistical Computing, Vienna, Austria) was used for data analysis. In this study, the Kolmogorov–Smirnov method was used to determine whether a quantitative variable followed a normal distribution; if it did not follow a normal distribution, the results were expressed as median (interquartile range), and the differences were compared using the Mann-Whitney *U* test. If the data followed a normal distribution, mean (standard deviation) was used to represent the results, and differences were compared using the *t*-test. For categorical variables such as gender, the results were expressed as frequency (percentage), and differences were compared using the chi-square test. Multifactorial analysis of the parameters measured by QIMT and QAS technology utilized multiple linear regression analysis. The significance level for statistical tests was set at α=0.05, and P<0.05 indicated statistical significance. All tests were 2-tailed.

Results

Basic characteristics of participants

A total of 233 males and 248 females were included in this study (participant inclusion flowchart can be seen in Figure S7), with 178 males (62.46%) and 107 females (37.54%) being diagnosed with NAFLD. The prevalence of NAFLD was higher in males compared to females (χ^2=53.64, P<0.001). The NAFLD group had higher body mass index (BMI), SBP, DBP, TG, TC, LDL, FBG, and UA levels compared to the healthy control group (P<0.001). The median age of the participants was 46 years. We found that the IMT, a structural index for NAFLD, was higher in the NAFLD group compared to the healthy control group (z=4.715, P<0.001). Additionally, the values of arterial elastic function indices, such as PWV, α, and β, were also higher in the NAFLD group compared to the healthy control group (P<0.001), although CC was lower in the NAFLD group compared to the healthy control group (P<0.001). However, there was no statistically significant difference in the arterial elastic function indices Aix and DC between the 2 groups (*Table 1*).

QIMT and QAS data collection of each parameter in the distribution between NAFLD and the healthy control group

Figure 1A shows the distribution of carotid IMT in the normal and NAFLD groups. It can be seen that regardless of whether it is the normal group or the NAFLD group, there is no difference in the distribution of carotid IMT on the left and right sides (P=0.1139). However, the carotid IMT in the NAFLD group is significantly higher than that in the normal control group (P<0.001, z=4.715). By stratifying IMT by gender, it was found that female NAFLD patients had a significantly greater increase in carotid IMT compared to the normal control group, whereas the difference between the 2 groups in males was not statistically significant (*Figure 1B*). The QIMT technique can be used well for the measurement of carotid IMT, it is not related to the left and right sides, and it has good stability. The same patterns were found in the arterial elastic coefficients α, β, PWV, Aix, DC, and vascular CC as shown in *Figure 1C-1H*.

Interaction between QIMT and QAS collection parameters and detection indexes

Based on the scatter plots of the coupling effect of various indicators measured by QIMT and QAS techniques with TG, we obtained the following results: IMT, α, β, and PWV values have a significant positive correlation with TG in the human body (P<0.0001), and Aix, CC, and DC values also have a significant positive correlation with TG in the human body (P<0.0001) (*Figure 2*). There was no statistical difference in the distribution of IMT between men and women (*Figure 2B*).

The relationship between QIMT and QAS collection parameters and age

Scatter plots showing the correlation between age and parameters measured by QIMT and QAS technologies revealed that with increasing age, carotid IMT, coefficients α and β, PWV, and Aix all increased significantly (P<0.0001, *Figure 3*). This indicates a strong positive correlation between these measures and age. Conversely, the

Table 1 Differences in biochemical indicators between the healthy control group and the case group

Variable	Quantity (n=481)	Healthy control group (n=196)	NAFLD group (n=285)	P value	Statistic
Sex				<0.001*	χ^2=53.64
Male	233 (48.44)	55 (28.06)	178 (62.46)		
Female	248 (51.56)	141 (71.94)	107 (37.54)		
Age (years)	46 [34, 56]	44 [34, 55]	47 [34, 56]	0.397	z=0.847
BMI (kg/m^2)	24.3 [22.21, 26.72]	22.185 [20.28, 24.05]	25.83 [23.89, 27.78]	<0.001*	z=11.859
Systolic blood pressure (mmHg)	127 [118, 135]	120.5 [112, 129]	131 [121, 137]	<0.001*	z=7.842
Diastolic blood pressure (mmHg)	80 [75, 86]	78 [71, 83]	83 [78, 88]	<0.001*	z=7.04
TG (mmol/L)	1.35 [0.97, 2.12]	0.97 [0.77, 1.21]	1.94 [1.34, 2.7]	<0.001*	z=13.84
TC (mmol/L)	4.68 [4.13, 5.22]	4.4 [3.94, 4.86]	4.88 [4.34, 5.45]	<0.001*	z=6.791
LDL (mmol/L)	2.62 [2.15, 3.02]	2.47 [2.078, 2.81]	2.76 [2.27, 3.15]	<0.001*	z=4.933
HDL (mmol/L)	1.145 [0.95, 1.39]	1.335 [1.16, 1.53]	1.035 [0.91, 1.2]	<0.001*	z=10.27
FBG (mmol/L)	5.195 [4.86, 5.56]	5.1 [4.745, 5.41]	5.26 [4.957, 5.70]	<0.001*	z=4.174
UA (μmol/L)	333 [265, 40]	276 [233.75, 324.25]	374 [321, 441]	<0.001*	z=11.487
IMT (mm)	615 [546, 708]	580.5 [514, 686.25]	636 [567, 734]	<0.001*	z=4.715
PWV (m/s)	6.83 [5.91, 7.87]	6.425 [5.547, 7.307]	7.24 [6.1, 8.24]	<0.001*	z=5.918
Aix (%)	11.89 [0.87, 22.75]	12.25 [2.245, 22.805]	11.07 [−0.17, 22.5]	0.153	z=1.429
α	3.81 [2.91, 4.84]	3.52 [2.745, 4.322]	4.08 [3.04, 5.28]	<0.001*	z=4.443
β	7.79 [6.01, 9.94]	7.28 [5.685, 8.845]	8.37 [6.26, 10.76]	<0.001*	z=4.415
DC (1/kPa)	0.02 [0.02, 0.03]	0.02 [0.02, 0.03]	0.02 [0.01, 0.03]	0.161	z=1.334
CC (mm^2/kPa)	1.14 [0.92,1.19]	1.21 [1.09, 1.32]	0.89 [0.76, 1.06]	<0.001*	Z=4.627

Data are presented as n (%) or median [IQR]. *, the difference was statistically significant. NAFLD, non-alcoholic fatty liver disease; BMI, body mass index; TG, triglycerides; TC, total cholesterol; LDL, low-density lipoprotein; HDL, high-density lipoprotein; FBG, fasting blood glucose; UA, uric acid; IMT, intima-media thickness; PWV, pulse wave velocity; Aix, augmentation index; α, stiffness parameter α; β, stiffness parameter β; DC, distensibility coefficient; CC, compliance coefficient; IQR, interquartile range.

measurement of vascular CC decreased with age, which was also statistically significant (P<0.0001), showing a notable negative correlation with age. These findings suggest that as age increases, carotid IMT rises and elastic function deteriorates. However, there was no statistical difference in the distribution of IMT between men and women in different ages (*Figure 3B*).

The scatter plot showing the relationships between various parameters measured by QIMT and QAS techniques and age revealed that with increasing age, the measured values of IMT, vascular elasticity coefficients α and β, PWV, and Aix all increased significantly (P<0.0001). This indicates a significant positive correlation between IMT, α, β, PWV, Aix, and age. However, with increasing age, the measured value of the vascular CC decreased significantly (P<0.0001), indicating a significant negative correlation between CC and age. We observed that with advancing age, IMT increases, indicating a deterioration in elastic function. Distribution plots of QIMT and QAS collection parameters with other variables can be found in Figures S8-S15.

NAFLD patients: a multivariate analysis of the relationship with various parameters of QIMT and QAS technology

According to the multivariate analysis results displayed in *Table 2*, gender, age, SBP, and UA all have a relationship

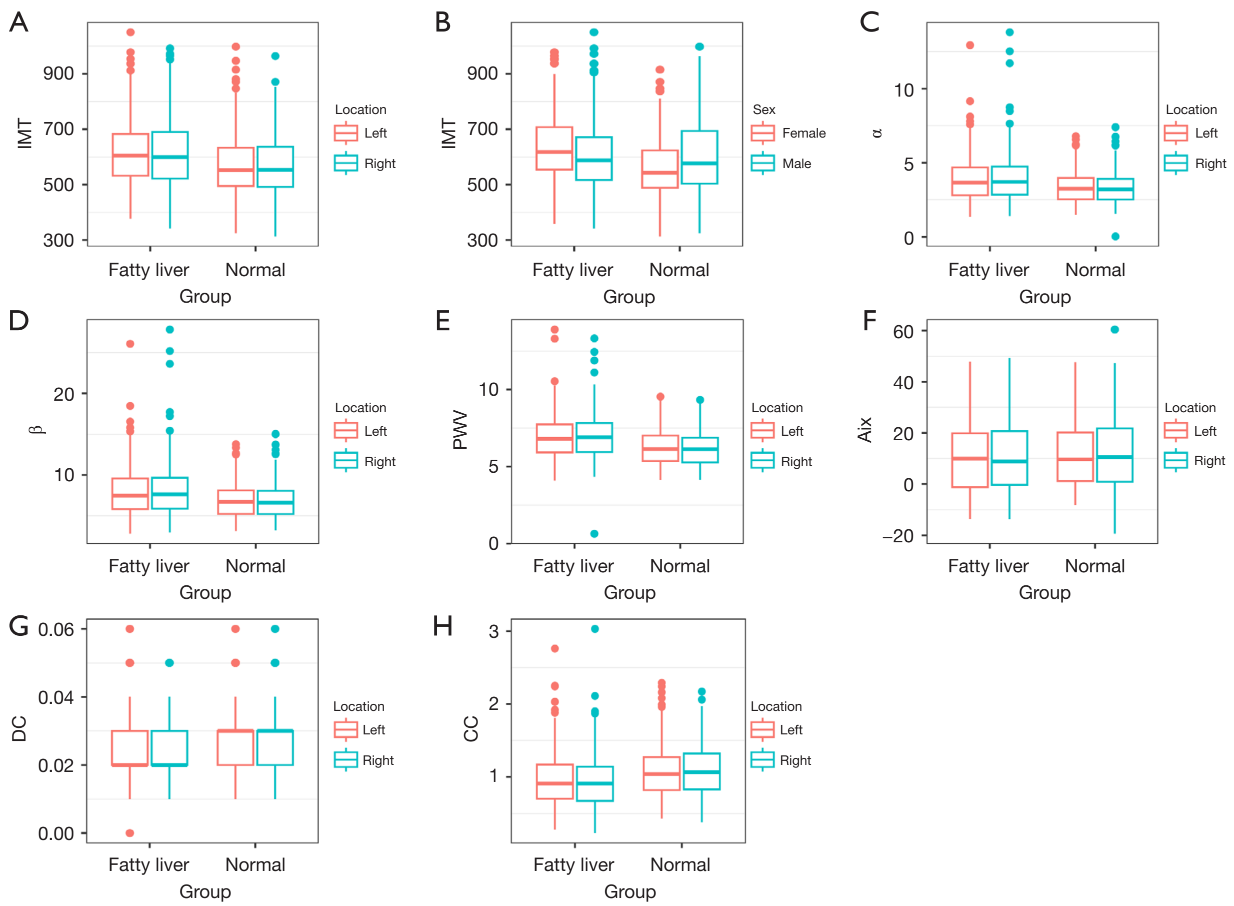

Figure 1 Distribution of QIMT and QAS parameters between NAFLD and healthy control groups. IMT, intima-media thickness; α, stiffness parameter α; β, stiffness parameter β; PWV, pulse wave velocity; Aix, augmentation index; DC, distensibility coefficient; CC, compliance coefficient; QIMT, Quality Intima-Media Thickness; QAS, Quantitative Artery Stiffness; NAFLD, non-alcoholic fatty liver disease.

with carotid IMT. The multivariate analysis results from Table S1 show that the presence of NAFLD, age, SBP, DBP, and UA all have a relationship with arterial elasticity index α. The multivariate analysis results displayed in Table S2 indicate that the presence of NAFLD, age, SBP, DBP, HDL, and UA all have a relationship with arterial elasticity index β. The multivariate analysis results from Table S3 show that the presence of NAFLD, age, SBP, and UA all have a relationship with PWV. The multivariate analysis results from Table S4 indicate that the presence of NAFLD, gender, age, SBP, DBP, and UA all have a relationship with Aix. The multivariate analysis results from Table S5 show that the presence of NAFLD, age, BMI, SBP, and HDL all have a relationship with vascular DC. The multivariate analysis results from Table S6 suggest that the presence of NAFLD, age, SBP, DBP, HDL, and UA all have a relationship with CC.

Discussion

Carotid ultrasound is one of the most important diagnostic methods for early assessment of vascular lesions. Conventional ultrasound and elasticity examination methods in the past were manually performed by medical experts, with significant subjective influences. The results were severely limited by intra- and inter-observer errors, as well as differences in equipment and data samples. In contrast, QIMT and QAS technologies are based on automatic tracking and measurement of arterial wall using RF signals, followed by analysis of relevant data. They

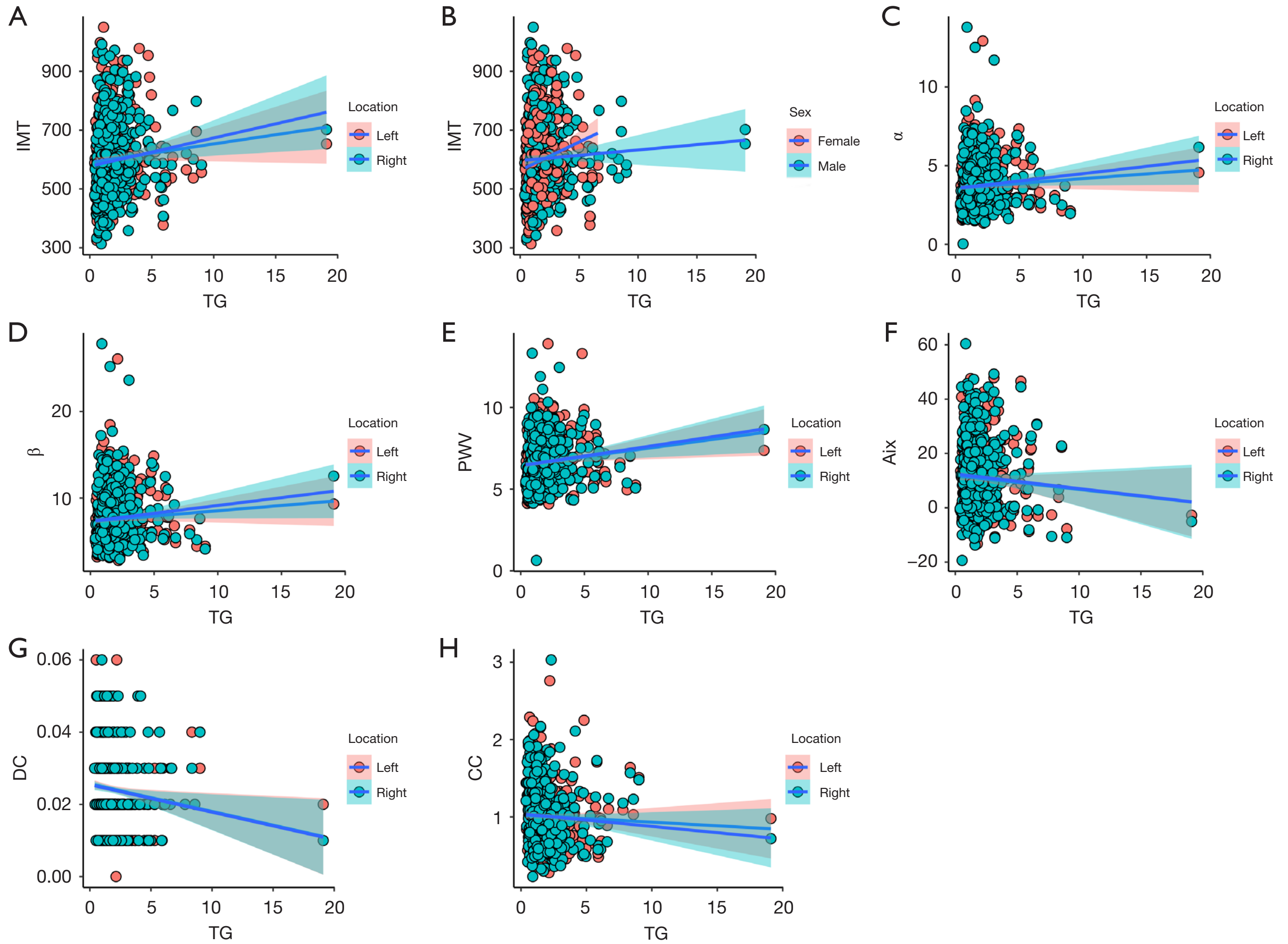

Figure 2 Relationship between QIMT and QAS collection parameters and triglycerides. IMT, intima-media thickness; TG, triglycerides; α, stiffness parameter α; β, stiffness parameter β; PWV, pulse wave velocity; Aix, augmentation index; DC, distensibility coefficient; CC, compliance coefficient; QIMT, Quality Intima-Media Thickness; QAS, Quantitative Artery Stiffness.

automatically acquire data, thus eliminating the influence of human factors. Compared to conventional ultrasound examinations, this method provides more accurate, objective, and comprehensive measurements, is non-invasive, convenient, and exhibits good repeatability. It holds significant advantages in the diagnosis of CA diseases. The association between quantitative indicators brought by QIMT and QAS technologies and NAFLD disease is a crucial step in applying these technologies for evaluating carotid arteries in NAFLD patients. Therefore, this study comprehensively evaluates the vascular structure and elasticity of CAs in NAFLD patients using QIMT and QAS technologies, comparing them with a healthy control group to observe changes in the vascular structure and function of carotid arteries in NAFLD patients, and to investigate whether NAFLD is related to various quantitative parameters of carotid arteries.

The univariate analysis of this study shows that the IMT among NAFLD patients is higher than that in the healthy control group, whereas the vascular elasticity function indicators such as PWV, α, β, and CC are significantly higher in the NAFLD group compared to the healthy control group. However, there is no statistically significant difference in the vascular elasticity function indicators Aix and DC between the two groups. The results of multivariate analysis show that gender, age, SBP, DBP, LDL, and UA all have a relationship with the IMT values of CAs. The presence of NAFLD does not have a statistically significant

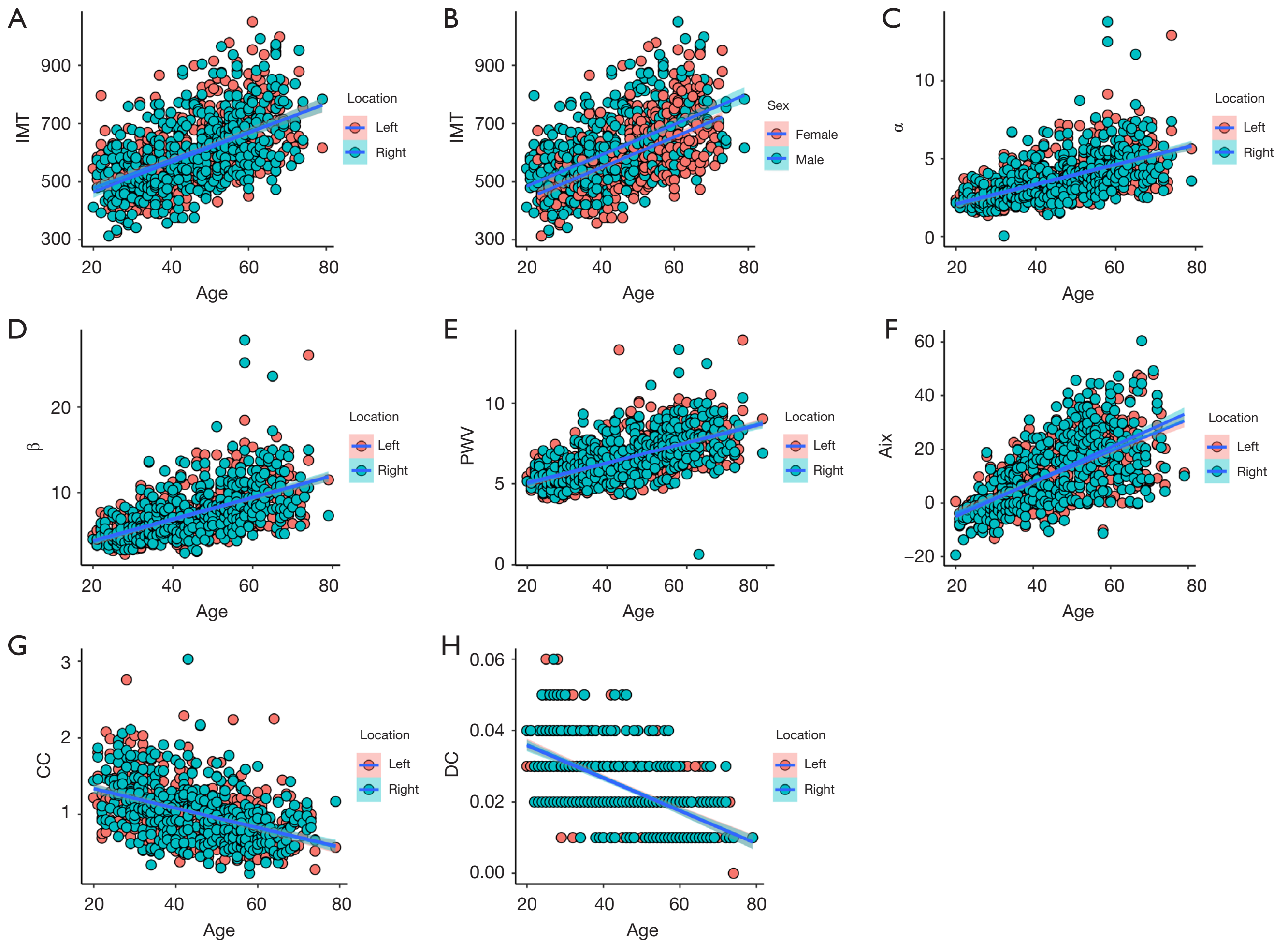

Figure 3 Scatter plot showing the coupling effect between various parameters measured by QIMT and QAS techniques and age. QIMT, Quality Intima-Media Thickness; QAS, Quantitative Artery Stiffness; IMT, intima-media thickness; PWV, pulse wave velocity; DC, distensibility coefficient; CC, compliance coefficient; Aix: augmentation index; α, stiffness parameter α; β, stiffness parameter β.

effect on the vascular structure indicator IMT, whereas NAFLD is mainly related to vascular elasticity indicators such as α, β, PWV, Aix, DC, and CC. Additionally, age, SBP, DBP, HDL, and UA all have a relationship with the vascular elasticity coefficient β; age, SBP, and UA all have a relationship with PWV; gender, age, SBP, DBP, and UA all have a relationship with Aix; age, BMI, SBP, and HDL all have a relationship with the DC; and age, SBP, DBP, HDL, and UA all have a relationship with the CC of blood vessels. The correlation between various indicators in the study and carotid IMT and arterial elasticity indicators is generally consistent with previous literature research results.

Based on the statistical results above, it can be concluded that NAFLD is significantly related to PWV, α, β, CC, and DC, which are 5 categories of indicators. These indicators are related to the elastic function of the CA, suggesting that NAFLD is significantly related to the CA's elastic function. Additionally, we found that the influence of NAFLD on carotid IMT was not statistically significant, with gender, age, SBP, DBP, LDL, and UA having a relationship with IMT, which is consistent with previous research results. Tarantino *et al.* found that age and interleukin (IL)-15 levels were both predictors of early atherosclerosis in this population of obese patients with NAFLD, suggesting a possible role of this cytokine in the atherosclerosis process (36). Therefore, using QIMT and QAS techniques for CA evaluation in NAFLD patients, focusing on changes in elastic function is more meaningful than changes in

Table 2 Results of multivariate analysis on factors related to carotid IMT values

Variable	Estimated value (95% CI)	Standard error	*t*	P value
Coefficient	5.651 (5.476, 5.825)	0.0878	63.651	<0.0001*
Group fatty liver	0.008 (–2.205, 0.038)	0.0154	0.531	0.5955
Gender (female)	–0.031 (–0.059, –0.004)	0.0416	–2.221	0.0266*
Age	0.008 (0.008, 0.009)	0.0005	18.154	<0.0001*
BMI	0.003 (–0.0006, 0.006)	0.0018	1.624	0.1048
Systolic blood pressure	0.002 (0.0007, 0.003)	0.0007	3.048	0.0024*
Diastolic blood pressure	–0.002 (–0.0036, 0.0003)	0.0010	–1.628	0.1038
Log (TG)	0.003 (–0.037, 0.031)	0.1743	–0.167	0.8676
Cholesterol	–0.004 (–0.042, 0.033)	0.0186	–0.203	0.8390
LDL	0.039 (–0.002, 0.080)	0.0207	1.876	0.0610
HDL	0.013 (–0.071, 0.044)	0.0293	–0.457	0.6476
Blood sugar	0.006 (–0.008, 0.021)	0.0074	0.833	0.4051
UA	0.0002 (0.00003, 0.0003)	<0.0001	2.007	0.0450*

*, the difference was statistically significant. IMT, intima-media thickness; CI, confidence interval; BMI, body mass index; TG, triglycerides; LDL, low-density lipoprotein; HDL, high-density lipoprotein; UA, uric acid.

structure. This view is consistent with numerous studies both within China and internationally, where changes in arterial elastic function often precede changes in arterial structure. Accurately assessing early arterial elastic functional changes in atherosclerosis is important for the early prevention and treatment of cardiovascular diseases (37,38). The decline in arterial elastic function is one of the early manifestations of cardiovascular events, so arterial elastic function testing is clinically significant in predicting the occurrence and development of cardiovascular complications (39). The changes in CA elastic function in NAFLD patients are mainly related to disturbances in lipid metabolism within the body: (I) elevated cholesterol is typically first related to dysfunction of small arterial endothelial cells, leading to reduced secretion of endothelium-dependent vasodilators, decreased vascular compliance, and reduced arterial elasticity (40). (II) The status of high TG as an independent risk factor for atherosclerosis has long been debated. (III) LDL is the most atherogenic lipoprotein, residing in plasma for long periods and difficult to clear from the bloodstream, readily entering the arterial intima, susceptible to oxidation, being engulfed by macrophages to form foam cells, and having a highly atherogenic effect (41). (IV) HDL has anti-atherosclerotic effects, being able to reverse transport cholesterol, directly or indirectly transporting excess cholesterol from the arterial wall to the liver for breakdown and metabolism via specific receptor pathways (42).

The study also has limitations and shortcomings. The number of participants in this study, especially in the elderly group, was not sufficient. It will be necessary to further expand the sample size and balance the number of cases in both groups to verify the preliminary research results obtained in this study. The majority of the participants were from Zhejiang Province, and therefore the sample cannot represent the population of different regions, corresponding diet, and lifestyle habits on carotid IMT and elastic indicators. Future studies could expand the collection of samples from different racial populations in different regions for research purposes. Additionally, the study's average test duration per person was 15–20 minutes, which is relatively long. Therefore, most cases involved single or double measurements, with few cases involving multiple measurements. The repeatability of double measurements was high, but the repeatability of multiple measurements could not be evaluated. Consequently, it will be necessary to use a more frequent measurement method in future studies to validate the preliminary research results obtained in this study. We did not analyze surrogate markers, such as homeostasis model assessment (HOMA) or triglyceride-glucose (TyG), to reflect insulin resistance. Our future research will focus on analyzing surrogate markers, such as HOMA or TyG, to reflect insulin resistance and explore the relationship between insulin resistance and NAFLD. Sarcopenia is a well-recognized geriatric syndrome associated with various adverse outcomes and is a condition observed in multiple diseases. Low skeletal muscle mass has been independently linked to the presence of carotid atherosclerosis (43). However, a limitation of this study is that sarcopenia was not investigated, and patients were not classified based on the presence of sarcopenia. Moving forward, we will primarily use QIMT and QAS techniques to conduct a comprehensive evaluation of changes in CA IMT and elasticity in NAFLD patients with sarcopenia. Given the current focus on metabolic health and cardiovascular metabolic risk groups (44), this study plans to use existing research findings to help stratify cardiovascular metabolic risk in patients with hepatic steatosis. This study lacks some important variables, such as dietary intake, physical activity, socioeconomic status, and the distribution of participants from rural versus urban areas. Our future research will include these variables for further investigation.

Conclusions

NAFLD patients exhibit significantly increased CA IMT and diminished elasticity compared to healthy controls. Additionally, with increasing age, CA IMT significantly increases, while elasticity function significantly deteriorates. NAFLD may be significantly related to vascular elasticity indicators α, β, PWV, Aix, DC, and CC. RF signal QIMT and QAS techniques can reflect changes in CA structure and elasticity function in NAFLD patients, which can be more widely applied and promoted in the changes of CA structure and elastic function in NAFLD patients.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The research was conducted in accordance with good clinical practice guidelines and the Declaration of Helsinki (as revised in 2013). The protocol and amendments have been approved by the Ethics Committee of Lishui People's Hospital (No. 2024-007) and the Ethics Committee of The First Affiliated Hospital, Zhejiang University School of Medicine [2021 ITT Fast Track Review No. (806)]. Informed consent was provided by all individual participants.

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