

Clinical and Biochemical Predictors of Significant Liver Fibrosis in Patients with Fatty Liver Disease: A Cross-Sectional Observational Study

¹Dr. Aditya Singh Kutiyal, Associate Professor, Department of General Medicine, Rama Medical College Hospital and Research Centre, Kanpur, Uttar Pradesh, India.

Corresponding Author: Dr. Aditya Singh Kutiyal, Associate Professor, Department of General Medicine, Rama Medical College Hospital and Research Centre, Kanpur, Uttar Pradesh, India.

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Abstract

Background: Metabolic dysfunction-associated steatotic liver disease (MASLD), formerly termed non-alcoholic fatty liver disease (NAFLD), is common in India. Fibrosis stage is closely related to long-term liver outcomes, but liver biopsy is not suitable for routine assessment. Non-invasive tests such as FIB-4, the NAFLD Fibrosis Score (NFS), and VCTE provide practical alternatives.

Objective: To identify clinical, anthropometric, and routine biochemical predictors of significant liver fibrosis among adults with ultrasonographically detected fatty liver disease and to assess the diagnostic performance of selected non-invasive fibrosis markers.

Methods: This hospital-based cross-sectional observational study included 150 consecutive adults with fatty liver disease seen at Rama Medical College Hospital & Research Centre, Kanpur, between September 2025 and June 2026. Participants underwent clinical

assessment, anthropometry, fasting laboratory investigations, abdominal ultrasonography, and VCTE. Significant fibrosis was defined as LSM ≥ 8.2 kPa according to INASL guidance. Logistic regression and receiver operating characteristic (ROC) analyses were performed.

Results: The mean age was 49.4 ± 10.5 years and 57.3% of participants were men. Significant fibrosis was present in 44 participants (29.3%); 14 (9.3%) had LSM ≥ 13.6 kPa. In multivariable analysis, age (adjusted odds ratio [aOR] 1.09, 95% CI 1.02–1.17; $p=0.008$), BMI (aOR 1.19, 95% CI 1.02–1.40; $p=0.030$), type 2 diabetes (aOR 4.88, 95% CI 1.57–15.13; $p=0.006$), AST (aOR 1.10, 95% CI 1.05–1.16; $p<0.001$), and platelet count (aOR 0.98, 95% CI 0.97–0.99; $p<0.001$) were independent predictors. NFS had the highest AUROC (0.870), followed by AST (0.831), albumin (0.824), and FIB-4 (0.809).

Conclusion: Significant fibrosis was found in nearly one-third of the participants in this study. Age, BMI, diabetes, AST, and platelet count were independently associated with fibrosis. The findings support sequential risk assessment using simple clinical variables and FIB-4, followed by VCTE in patients who remain at intermediate or high risk.

Keywords: MASLD, Fatty Liver Disease, Hepatic Fibrosis, Transient Elastography, FIB-4, NAFLD Fibrosis Score, Type 2 Diabetes Mellitus, Biomarkers.

Introduction

Steatotic liver disease is now the most common chronic liver disorder in many regions, and the terminology has shifted from NAFLD to MASLD to better describe the metabolic context of hepatic steatosis¹. In India, the burden is substantial; a systematic review and meta-analysis estimated a pooled adult NAFLD prevalence of 38.6%, with higher estimates in hospital-based populations². The disease ranges from uncomplicated steatosis to steatohepatitis, progressive fibrosis, cirrhosis, and hepatocellular carcinoma.

Among these stages, fibrosis is particularly important because increasing fibrosis stage is associated with liver-related events, transplantation, and mortality³. This makes identifying patients with clinically significant fibrosis an important component of current fatty liver disease care.

Liver biopsy remains the histological reference standard, but it is invasive and affected by sampling variability. Guidelines recommend non-invasive testing for routine practice. INASL recommends FIB-4 or APRI for initial assessment and VCTE for further evaluation when the initial risk is intermediate or high⁴. The INASL guidance uses LSM <6.0 kPa as a range in which significant fibrosis is unlikely, ≥8.2 kPa for significant fibrosis (≥F2), and ≥13.6 kPa for cirrhosis-range stiffness [4]. VCTE has also

shown useful diagnostic accuracy for clinically important fibrosis in systematic reviews.

FIB-4 is calculated from age, AST, ALT, and platelet count and was originally developed as a simple non-invasive fibrosis index⁵. The NFS combines age, BMI, glycemic status, AST/ALT ratio, platelet count, and albumin⁶. Both scores are incorporated into contemporary risk-stratification pathways^{3,7}.

The present study was undertaken to examine the clinical and biochemical factors associated with significant fibrosis in a tertiary-care cohort in northern India. A second aim was to compare the discriminatory performance of FIB-4, NFS, and selected routine laboratory variables against an elastography-defined fibrosis endpoint.

Material and Methods

Study design and setting

This prospective, hospital-based, cross-sectional observational study was conducted at Rama Medical College Hospital & Research Centre, Kanpur, Uttar Pradesh, India, over 10 months from September 2025 to June 2026. Participants were included from the outpatient and inpatient services of the Department of Medicine, with radiology and biochemistry support. This study was approved by the Institutional Ethics Committee of Rama Medical College Hospital & Research Centre and was conducted in accordance with the Declaration of Helsinki and the ethical guidelines of the Indian Council of Medical Research. Written informed consent was obtained from all participants.

Participants

In this study, Adults aged 18 years or older with hepatic steatosis on transabdominal B-mode ultrasonography, complete clinical and laboratory records, written informed consent, and a technically valid VCTE

examination were included. Exclusion criteria were significant alcohol consumption (>20 g/day in women or >30 g/day in men), chronic hepatitis B or C, autoimmune liver disease, inherited metabolic liver disease, cirrhosis of another known cause, active malignancy, recent exposure to selected steatogenic or hepatotoxic drugs, severe acute systemic illness, pregnancy or lactation, and conditions likely to interfere with VCTE measurements, including gross ascites, severe right-sided heart failure, major chest-wall deformity, or acute extrahepatic biliary obstruction.

Clinical and anthropometric assessment

In present study, Age, sex, diabetes, hypertension, dyslipidemia, medication history, weight, height, BMI, and waist circumference were recorded using a structured proforma. Hypertension was defined as blood pressure $\geq 140/90$ mmHg or current antihypertensive treatment. Type 2 diabetes was based on established clinical documentation, glucose-lowering treatment, fasting plasma glucose ≥ 126 mg/dL, or HbA1c $\geq 6.5\%$.

Laboratory investigations

After an overnight fast of 10–12 hours, blood was collected for complete blood count, liver biochemistry, glucose, HbA1c, lipid profile, and creatinine. AST, ALT, alkaline phosphatase, bilirubin, total protein, albumin, fasting glucose, HbA1c, triglycerides, total cholesterol, HDL cholesterol, LDL cholesterol, and creatinine were measured using automated laboratory platforms. Platelet count was obtained from the automated hematology analyzer.

Ultrasonography and VCTE

Abdominal ultrasonography was performed by certified radiologists who were blinded to the clinical and biochemical data. Steatosis was graded as mild, moderate,

or severe according to the sonographic criteria described in the source protocol.

Liver stiffness was measured with FibroScan 502 Touch (Echosens, Paris, France). Patients fasted for at least 3 hours before examination. The M probe was used initially, with XL-probe selection when the skin-to-liver capsule distance exceeded 25 mm. At least 10 valid acquisitions, a success rate $\geq 60\%$, and an interquartile range/median ratio $\leq 30\%$ were required. The median LSM was used for analysis. The primary endpoint was significant fibrosis, defined as LSM ≥ 8.2 kPa; LSM ≥ 13.6 kPa was classified as cirrhosis-range stiffness⁴.

Non-invasive fibrosis scores

FIB-4 was calculated as: $FIB-4 = [\text{age (years)} \times \text{AST (U/L)}] / [\text{platelets (10}^9/\text{L)} \times \sqrt{\text{ALT (U/L)}}]$ [5]. Risk categories were 2.67. NFS was calculated using the published formula incorporating age, BMI, impaired fasting glucose/diabetes, AST/ALT ratio, platelet count, and albumin⁶.

Statistical analysis

In this study, Continuous variables were assessed for distribution using the Shapiro–Wilk test and visual inspection of Q–Q plots. Normally distributed data were summarized as mean $\pm$ SD; non-normal variables were summarized as median (IQR). Categorical variables were reported as counts and percentages. Between-group comparisons used the independent-samples t test, Mann–Whitney U test, Pearson χ^2 test, or Fisher exact test as appropriate.

Correlations with continuous LSM were examined using Pearson or Spearman coefficients. Binary logistic regression was used to identify independent predictors of LSM ≥ 8.2 kPa. Variables with biological plausibility and $p < 0.10$ on univariate analysis were considered for multivariable modeling. FIB-4 and NFS were excluded

from the multivariable model because their component variables were entered separately. Results are presented as odds ratios with 95% confidence intervals. ROC curves were assessed using the non-parametric DeLong method,

Results

Participant characteristics

A total of 150 adults with ultrasonographically confirmed fatty liver disease were included. The mean age was 49.4 ± 10.5 years, 86 (57.3%) were men, and the mean BMI was 27.4 ± 3.8 kg/m². Type 2 diabetes was present in 66

and optimal cut-offs were identified using Youden's index. A two-sided $p < 0.05$ was considered statistically significant.

(44.0%) participants and hypertension in 83 (55.3%). Mean AST, ALT, platelet count, albumin, FIB-4, NFS, and LSM were 39.3 ± 14.1 U/L, 48.5 ± 19.2 U/L, $206.0 \pm 52.2 \times 10^9$ /L, 4.00 ± 0.39 g/dL, 1.61 ± 0.98 , -1.13 ± 1.46 , and 7.45 ± 2.42 kPa, respectively.

Table 1. Baseline demographic, clinical, anthropometric, and laboratory characteristics of the study cohort (N=150)

Parameter	Significant fibrosis LSM ≥ 8.2 kPa (n=44)	No significant fibrosis LSM < 8.2 kPa (n=106)	Test statistic	p value
Age, years	55.1 ± 7.5	47.1 ± 10.7	4.54	< 0.001
Male sex, n (%)	26 (59.1)	60 (56.6)	0.08	0.781
Female sex, n (%)	18 (40.9)	46 (43.4)	—	—
BMI, kg/m ²	29.5 ± 3.5	26.6 ± 3.5	4.60	< 0.001
Type 2 diabetes, n (%)	28 (63.6)	38 (35.8)	9.77	0.003
Hypertension, n (%)	32 (72.7)	51 (48.1)	7.74	0.010
AST, U/L	51.2 ± 14.1	34.4 ± 10.9	7.91	< 0.001
ALT, U/L	60.2 ± 20.3	43.7 ± 16.5	5.29	< 0.001
AST/ALT ratio	0.89 ± 0.22	0.83 ± 0.22	1.54	0.126
Platelets, $\times 10^9$ /L	169.9 ± 41.6	220.9 ± 48.8	-6.11	< 0.001
Albumin, g/dL	3.67 ± 0.40	4.14 ± 0.29	-8.06	< 0.001
Total bilirubin, mg/dL	0.92 ± 0.34	0.86 ± 0.30	1.07	0.286
Fasting glucose, mg/dL	132.1 ± 38.9	112.7 ± 30.3	3.28	0.001
HbA1c, %	6.95 ± 1.34	6.14 ± 1.19	3.69	< 0.001
Triglycerides, mg/dL	177.8 ± 60.8	156.8 ± 59.6	1.93	0.056
Total cholesterol, mg/dL	188.5 ± 41.2	182.4 ± 37.5	0.88	0.380
Creatinine, mg/dL	0.94 ± 0.24	0.90 ± 0.21	1.04	0.301
FIB-4	2.41 ± 1.07	1.28 ± 0.72	7.64	< 0.001
NFS	-0.09 ± 1.25	-1.56 ± 1.31	6.36	< 0.001
LSM, kPa	10.64 ± 1.92	6.13 ± 0.88	19.86	< 0.001

Continuous variables are presented as mean $\pm$ SD; categorical variables as frequency (%). p values are two-sided.

Fibrosis categories,

In this study, seventy participants (46.7%) had LSM <6.0 kPa, 36 (24.0%) had LSM 6.0–8.19 kPa, and 44 (29.3%) had LSM ≥ 8.2 kPa. Fourteen participants (9.3%) had LSM ≥ 13.6 kPa; this group was nested within the significant-fibrosis group.

Table 2. Distribution of the cohort across liver stiffness measurement categories

LSM category	Clinical interpretation	N	%
<6.0 kPa	Significant fibrosis unlikely	70	46.7
6.0–8.19 kPa	Indeterminate/intermediate	36	24.0
≥ 8.2 kPa	Significant fibrosis ($\geq F2$)	44	29.3
≥ 13.6 kPa*	Cirrhosis-range stiffness (F4)	14	9.3
Total	—	150	100.0

*The ≥ 13.6 -kPa category is nested within the ≥ 8.2 -kPa group.

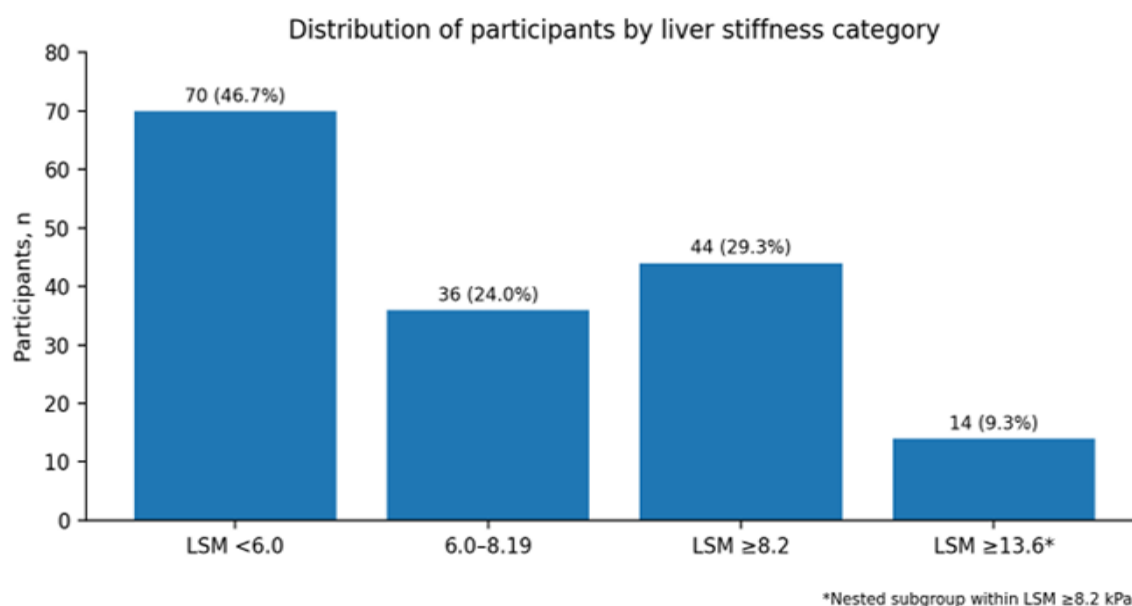


Figure 1: Distribution of participants across liver stiffness categories. The ≥ 13.6 -kPa category is a nested subgroup within the ≥ 8.2 -kPa group.

FIB-4 risk categories

In Present study, Across the full cohort, 76 participants (50.7%) had FIB-4 <1.30 , 48 (32.0%) had FIB-4 1.30–2.67, and 26 (17.3%) had FIB-4 >2.67 . Among participants with significant fibrosis, 20 (45.5%) were in the high-risk FIB-4 category, compared with 6 (5.7%) among those without significant fibrosis ($\chi^2=36.85$, $df=2$, $p<0.001$).

Table 3. FIB-4 risk categories by liver fibrosis status

FIB-4 category	Significant fibrosis (n=44)	No significant fibrosis (n=106)	Total (N=150)
Low risk (<1.30)	10 (22.7)	66 (62.3)	76 (50.7)
Intermediate (1.30–2.67)	14 (31.8)	34 (32.1)	48 (32.0)
High risk (>2.67)	20 (45.5)	6 (5.7)	26 (17.3)
Total	44 (100.0)	106 (100.0)	150 (100.0)

Percentages are calculated within each fibrosis-status column. $\chi^2=36.85$, $df=2$, $p<0.001$.

Correlation analysis

FIB-4 ($r=0.584$) and NFS ($r=0.547$) had the strongest positive correlations with LSM. Among individual variables, AST had the strongest positive correlation ($r=0.512$), while platelet count ($r=-0.495$) and albumin ($r=-0.481$) showed inverse associations. Triglycerides and total cholesterol were not significantly correlated with LSM.

Table 4. Correlation of liver stiffness measurement with explanatory variables

Variable	Correlation coefficient	Direction	p value
FIB-4	+0.584	Positive	<0.001
NFS	+0.547	Positive	<0.001
AST	+0.512	Positive	<0.001
Platelets	-0.495	Negative	<0.001
Albumin	-0.481	Negative	<0.001
Age	+0.386	Positive	<0.001
BMI	+0.362	Positive	<0.001
ALT	+0.344	Positive	<0.001
HbA1c	+0.338	Positive	<0.001
Fasting glucose	+0.312	Positive	<0.001
Triglycerides	+0.156	Positive	0.056
Total cholesterol	+0.156	Positive	0.380
Creatinine	+0.081	Positive	0.325

Pearson or Spearman correlation coefficients were used according to distribution.

Multivariable analysis

The study shown that five variables remained independently associated with significant fibrosis: age, BMI, type 2 diabetes, AST, and platelet count. Diabetes showed the largest effect estimate (aOR 4.88), while increasing platelet count was associated with lower odds of significant fibrosis. Hypertension, ALT, albumin, fasting glucose, and HbA1c did not remain independently significant after adjustment. The model had good calibration by the Hosmer–Lemeshow test ($\chi^2=5.84$, $df=8$, $p=0.665$) and an overall classification accuracy of 86.0%.

Table 5: Univariate and multivariable logistic regression for significant liver fibrosis

Candidate variable	Unadjusted OR (95% CI)	Univariate p	Adjusted OR (95% CI)	Multivariable p
Age (per 1 year)	1.10 (1.05–1.15)	<0.001	1.09 (1.02–1.17)	0.008
BMI (per 1 kg/m ²)	1.26 (1.13–1.41)	<0.001	1.19 (1.02–1.40)	0.030
Type 2 diabetes (present vs absent)	3.13 (1.51–6.50)	0.002	4.88 (1.57–15.13)	0.006
Hypertension (present vs absent)	2.88 (1.34–6.19)	0.007	1.45 (0.52–4.06)	0.478
AST (per 1 U/L)	1.11 (1.06–1.16)	<0.001	1.10 (1.05–1.16)	<0.001
ALT (per 1 U/L)	1.05 (1.03–1.08)	<0.001	0.99 (0.95–1.03)	0.582
Platelets (per 1×10 ⁹ /L)	0.97 (0.96–0.98)	<0.001	0.98 (0.97–0.99)	<0.001
Albumin (per 1 g/dL)	0.02 (0.004–0.09)	<0.001	0.38 (0.06–2.41)	0.306
Fasting glucose (per 10 mg/dL)	1.18 (1.06–1.31)	0.002	1.03 (0.88–1.21)	0.698
HbA1c (per 1%)	1.63 (1.23–2.16)	0.001	1.06 (0.68–1.65)	0.792
Triglycerides (per 10 mg/dL)	1.06 (0.99–1.13)	0.058	—	—

FIB-4 and NFS were not entered into the multivariable model because their component variables were modeled separately.

Hosmer–Lemeshow $\chi^2=5.84$, $df=8$, $p=0.665$; Nagelkerke $R^2=0.542$; overall classification accuracy=86.0%.

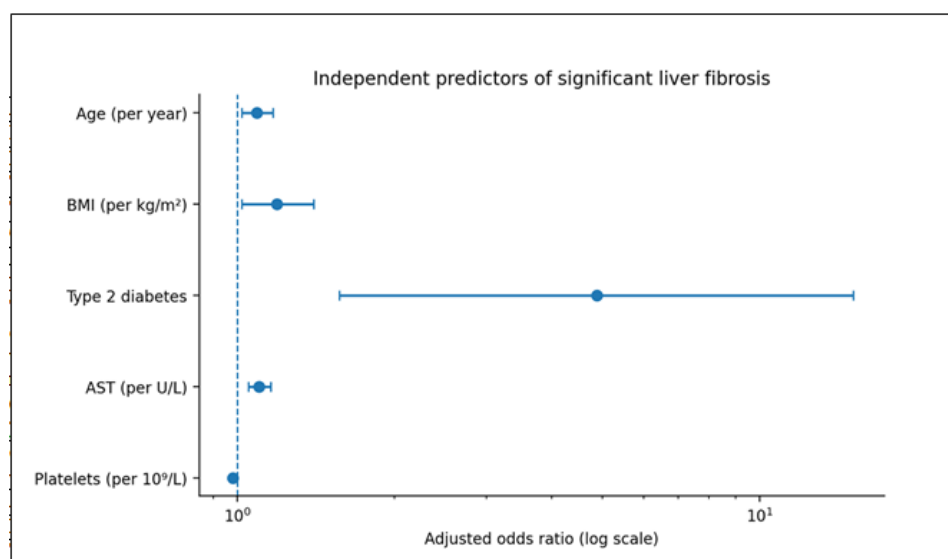


Figure 2: Adjusted odds ratios for independent predictors of significant liver fibrosis. Error bars represent 95% confidence intervals.

Diagnostic performance

In Present study it shows that, NFS had the highest AUROC at 0.870 (95% CI 0.805–0.920), followed by AST (0.831), albumin (0.824), FIB-4 (0.809), platelet count (0.791), BMI (0.734), and ALT (0.729). At the Youden-optimal threshold of

1.60, FIB-4 had 75.0% sensitivity and 77.4% specificity. NFS at -0.75 had 86.4% sensitivity and 80.2% specificity. AST ≥ 49.9 U/L had high specificity (94.3%) but lower sensitivity (65.9%).

Table 6. ROC diagnostic performance for identifying significant liver fibrosis (LSM ≥ 8.2 kPa)

Index / parameter	AUROC	95% CI	Optimal cut-off	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
NFS	0.870	0.805–0.920	-0.75	86.4	80.2	64.4	93.4
AST	0.831	0.761–0.887	49.9 U/L	65.9	94.3	82.9	87.0
Albumin	0.824	0.753–0.881	≤ 3.85 g/dL	75.0	82.1	63.5	88.8
FIB-4	0.809	0.737–0.869	1.60	75.0	77.4	57.9	88.2
Platelets	0.791	0.717–0.853	$\leq 185 \times 10^9$ /L	70.5	78.3	57.4	86.5
BMI	0.734	0.656–0.803	28.2 kg/m ²	72.7	72.6	52.5	86.5
ALT	0.729	0.650–0.798	58.7 U/L	54.5	84.0	58.5	81.7

For platelet count and albumin, lower values indicate higher fibrosis probability. AUROC was calculated using the non-parametric DeLong method.

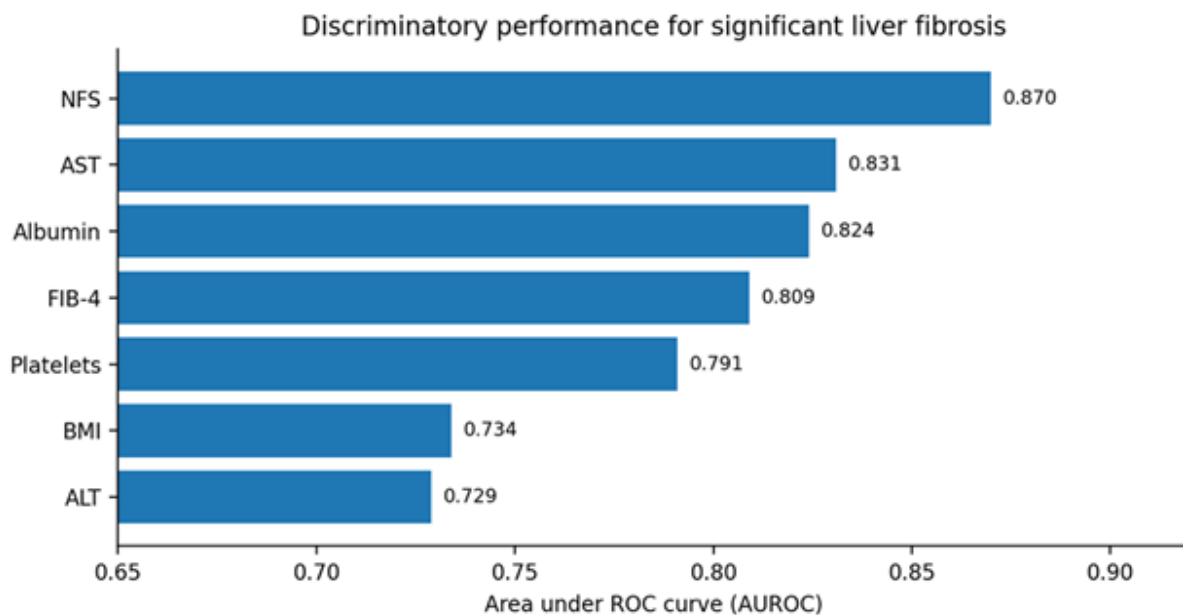


Figure 3: AUROC values for the principal non-invasive fibrosis scores and routine clinical/biochemical parameters.

Discussion

In this present study, adults with fatty liver disease, almost one in three participants had significant fibrosis by VCTE using the INASL threshold of 8.2 kPa. The 29.3% prevalence is higher than expected in unselected community populations but is plausible for a hospital cohort enriched for metabolic disease. Indian data show

that fatty liver disease is common overall and more frequent in hospital and high-risk populations².

The finding of this study, age was independently associated with fibrosis, is consistent with the cumulative nature of metabolic liver injury. Each additional year of age was associated with a 9% increase in the adjusted odds of significant fibrosis. Age is also a component of

FIB-4, which means that age-related increase in the score should be interpreted in context, particularly in older adult.^{5,7}

BMI remained independently associated with fibrosis after adjustment. The mean BMI was almost 3 kg/m² higher in the fibrosis group. In South Asian populations, cardiometabolic risk can occur at lower BMI than in many Western populations, and BMI therefore should not be used as a stand-alone exclusion criterion for fibrosis^{8,9}.

Type 2 diabetes was the strongest clinical predictor in the adjusted model, with an aOR of 4.88. This is clinically important because diabetes is strongly linked to steatotic liver disease and progression of fibrosis. The result supports guideline-based attention to fibrosis risk in patients with diabetes and fatty liver disease.

AST was independently associated with fibrosis, whereas ALT lost significance after adjustment. The result is compatible with the known limitation of aminotransferases: liver enzymes may be normal even in patients with advanced disease, so normal ALT or AST should not be used to exclude fibrosis^{3,7}. The relatively strong performance of AST in this cohort (AUROC 0.831) is useful as a clinical signal but does not justify using AST alone in place of validated fibrosis pathways. Platelet count was inversely associated with fibrosis. This is biologically plausible because progressive architectural distortion can be accompanied by portal hypertension and splenic sequestration of platelets. Platelet count is also part of FIB-4, providing a practical link between routine complete blood counts and fibrosis risk assessment⁵.

NFS had the highest AUROC in this cohort (0.870), slightly higher than FIB-4 (0.809). This difference may partly reflect the inclusion in NFS of BMI, diabetes, and albumin, variables that were associated with fibrosis in

the present cohort⁶. FIB-4, however, has an important practical advantage because it requires only age, AST, ALT, and platelet count and is recommended as a first-line risk assessment tool^{3,7}.

At the conventional FIB-4 cut-off of 2.67 had a specificity of 94.3%. The large intermediate group (32.0% of the cohort) illustrates why a second-line test such as VCTE is useful. This sequential strategy is consistent with INASL guidance and with broader evidence supporting non-invasive fibrosis assessment^{3,10,11}.

This study has several strengths like standardized clinical and laboratory assessment, predefined VCTE quality criteria, use of the Indian LSM thresholds, and multivariable adjustment of the main clinical and biochemical predictors. The main limitations are the cross-sectional design, single-centre recruitment, possible referral bias, and the use of VCTE rather than liver biopsy as the reference method. VCTE is a validated non-invasive tool, but liver stiffness can be affected by factors other than fibrosis, including inflammation, congestion, and biliary obstruction^{11,12}.

The findings should therefore be interpreted as evidence of association rather than causation. The reported prevalence should not be generalized to the Indian population as a whole. Larger multicentre prospective studies with longitudinal clinical outcomes would be useful for validating the predictors and local thresholds.

Clinical risk-stratification pathway

In practice, the study findings support a sequential approach: routine clinical assessment and FIB-4 as the first step, followed by VCTE in patients with intermediate or high risk. The INASL thresholds used in this study are shown in Figure 4, while the operating characteristics of selected thresholds are summarized in Table 7.

Table 7t. Sensitivity and false-positive rates at selected non-invasive test thresholds

Modality	Cut-off	Sensitivity	False-positive rate	Clinical use
NFS	-1.455	0.955	0.481	Rule-out
NFS	-0.750	0.864	0.198	Youden-optimal
NFS	+0.676	0.455	0.057	Rule-in
FIB-4	1.30	0.773	0.377	Rule-out
FIB-4	1.60	0.750	0.226	Youden-optimal
FIB-4	2.67	0.455	0.057	Rule-in
AST	49.9 U/L	0.659	0.057	High-specificity
BMI	28.2 kg/m ²	0.727	0.274	Discrimination
ALT	58.7 U/L	0.545	0.160	Intermediate

False-positive rate = 1 - specificity. Thresholds are reported from the supplied study analysis.

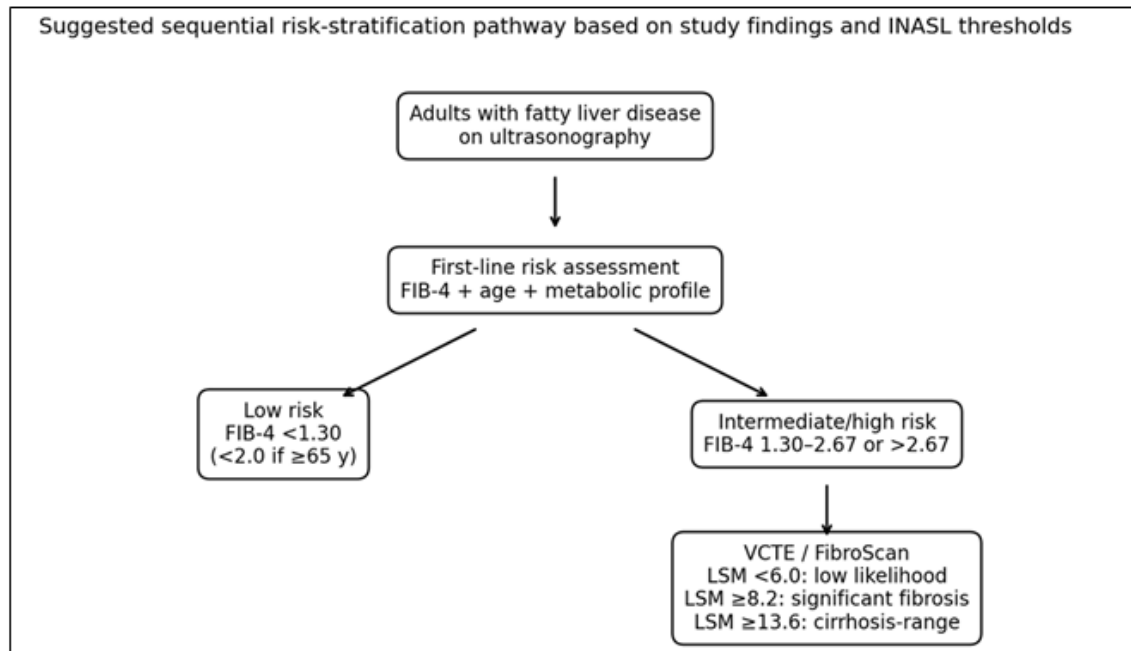


Figure 4. Practical sequential risk-stratification pathway based on the study findings and INASL thresholds.

Conclusion

In conclusion of present study, it was found that, significant liver fibrosis was detected by VCTE in 29.3% of adults with fatty liver disease in this tertiary-care cohort, while 9.3% had cirrhosis-range stiffness. Older age, higher BMI, type 2 diabetes, higher AST, and lower platelet count were independently associated with

significant fibrosis. NFS and FIB-4 both showed useful discrimination, with NFS performing best in this dataset. A practical approach is to use routine clinical data and FIB-4 as the first step and reserve VCTE for patients with intermediate or high risk. This approach is consistent with the current Indian guidelines and can help in identification of patients who require further liver assessment.

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