



Elastography of background liver in patients with focal hepatic lesions undergoing Triple Phase CT and its correlation with LI-RADS

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Abstract

Background: Differentiating between benign and malignant focal hepatic lesions in patients with chronic liver disease is critical for appropriate management. While imaging modalities such as triple-phase Computed Tomography (CT) and the Liver Imaging Reporting and Data System (LI-RADS) provide structured approaches for lesion characterization, they primarily focus on lesion morphology and enhancement patterns, often overlooking the role of the background liver parenchyma. Background liver stiffness assessment using elastography may provide additional insights in lesion characterization, particularly in cases where lesion enhancement patterns are atypical due to cirrhosis-related perfusion changes. This study evaluates the correlation between elastography-derived liver stiffness measurements and LI-RADS categorization of focal hepatic lesions identified on triple-phase CT.

Results: The majority of patients were in the 50–69 year age group (55.77%), with males comprising 61.54% of the study population. Liver stiffness values increased progressively with higher LI-RADS categories, with LR-TIV lesions exhibiting the highest mean stiffness (19.72 kPa). Spearman's rank correlation demonstrated a strong positive relationship between LI-RADS categories and liver stiffness measurements ($\rho = 0.79$, $p = 0.036$). In addition, a Chi-square test for association showed a statistically significant relationship between categorized liver stiffness levels and LI-RADS categories ($\chi^2 = 36.15$, $p = 0.00031$).

Conclusion: Elastography-derived liver stiffness correlates significantly with LI-RADS categorization, supporting its use as an adjunctive biomarker for focal hepatic lesion assessment. Integrating elastography with LI-RADS classification enhances diagnostic accuracy and may reduce the need for invasive biopsies. Further studies are warranted for validation in larger cohorts.

Keywords: Elastography, LI-RADS, focal hepatic lesions, liver stiffness, triple-phase CT

Background

Liver diseases, particularly focal hepatic lesions, are challenging to diagnose due to their diverse causes. These lesions range from benign conditions like hemangiomas and focal nodular hyperplasia to malignant ones like hepatocellular carcinoma (HCC) and metastases. Accurate differentiation is crucial as treatment varies based on whether a lesion is benign, pre-malignant, or malignant. Imaging techniques such as triple-phase CT and MRI help characterize lesions by assessing their structure and

blood supply. However, these methods mainly focus on lesion appearance and enhancement patterns, often overlooking the role of background liver tissue.¹

To standardize liver imaging, the American College of Radiology introduced the Liver Imaging Reporting and Data System (LI-RADS). This system classifies lesions from definitely benign (LI-RADS 1) to definitely HCC (LI-RADS 5) based on specific imaging features.^{2,3} While LI-RADS improves consistency in diagnosis, it does not directly assess liver stiffness, which is crucial in lesion development and progression. Chronic liver disease (CLD) causes fibrosis, altering liver structure and blood flow. These changes affect lesion appearance, sometimes leading to misclassification in LI-RADS⁴. Conditions like alcohol-related liver disease, non-alcoholic steatohepatitis, viral hepatitis, and autoimmune disorders contribute to CLD, increasing the risk of HCC.⁵

The METAVIR scoring system categorizes fibrosis severity from F0 (no fibrosis) to F4 (cirrhosis)⁶. While biopsy remains the gold standard for fibrosis assessment, non-invasive methods like transient elastography (FibroScan) provide alternative ways to measure liver stiffness⁶. Ultrasound elastography techniques, including shear wave elastography and magnetic resonance elastography, quantify liver stiffness in kilopascals (kPa) or meters per second (m/s)^{6, 7}. These methods correlate well with fibrosis stages and help predict disease severity⁷.

Previous studies have suggested that liver stiffness influences lesion behavior, with higher stiffness associated with a greater risk of HCC⁸. This study aims to analyze the correlation between elastography-derived liver stiffness and LI-RADS categorization in patients undergoing triple-phase CT. The objectives include assessing liver stiffness in patients with focal hepatic lesions, determining its correlation with LI-RADS categories, and evaluating whether stiffness values can serve as an additional imaging biomarker.

Methods

Study Design and Population

A hospital-based cross-sectional analytical study was conducted over 18 months (May 2023 – November 2024). The study focused on patients with focal hepatic lesions. A total of 51 patients were included.

Patients included underwent triple-phase CT and point shear wave elastography. Inclusion criteria involved adults with focal hepatic lesions. Exclusion criteria included cases in whom LIRADS is not applicable (such as those with cirrhosis due to vascular disorders), contraindications to elastography (such as gross ascites or patients unable to follow breath holding instructions), or those with no background liver free of lesion.

Imaging Protocols

Imaging was performed using a 128-slice Optima Wipro GE Healthcare CT scanner (2015, USA) and an EPIQ 7G Philips ultrasound machine (2018, USA).

The triple-phase CT scan protocol included non-enhanced scans, arterial, portal venous, and delayed phase imaging. Non-ionic contrast (Omnipaque) was injected at 3-4 ml/s using a pressure injector. Scans were performed in a cranio-caudal direction during deep inspiration breath-hold. Bolus tracking determined arterial phase timing.

Elastography was performed in accordance with the EFSUMB (European Federation of Societies for Ultrasound in Medicine and Biology) Guidelines and Recommendations.⁹ Liver stiffness was measured in kilopascals (kPa) using a convex transducer (3-5 MHz), as depicted in **Figure 1**. The patient was fasting for a minimum of 2 hours and resting for a minimum of ten minutes before undergoing liver stiffness measurement. The examinations were performed in the right lobe of the liver through intercostal spaces, with the subject lying supine with the right arm in maximal abduction. Using a real-time B-mode image, a vessel-free area, 4-5 cm below skin surface was selected, where a fixed region of interest of 0.5 cm × 1.5 cm was placed by moving a trackball. The patients were instructed to hold their breath during the data acquisition. Deep inspiration was avoided as Valsalva maneuver can increase liver stiffness and give a falsely high reading. Ten valid measurements were performed, which were expressed in kiloPascals, ensuring an interquartile range/median ratio of <0.3.

Care was taken to not include the focal hepatic lesions in liver stiffness assessment. Median stiffness values were categorized using the METAVIR scoring (**Fig. 2**).

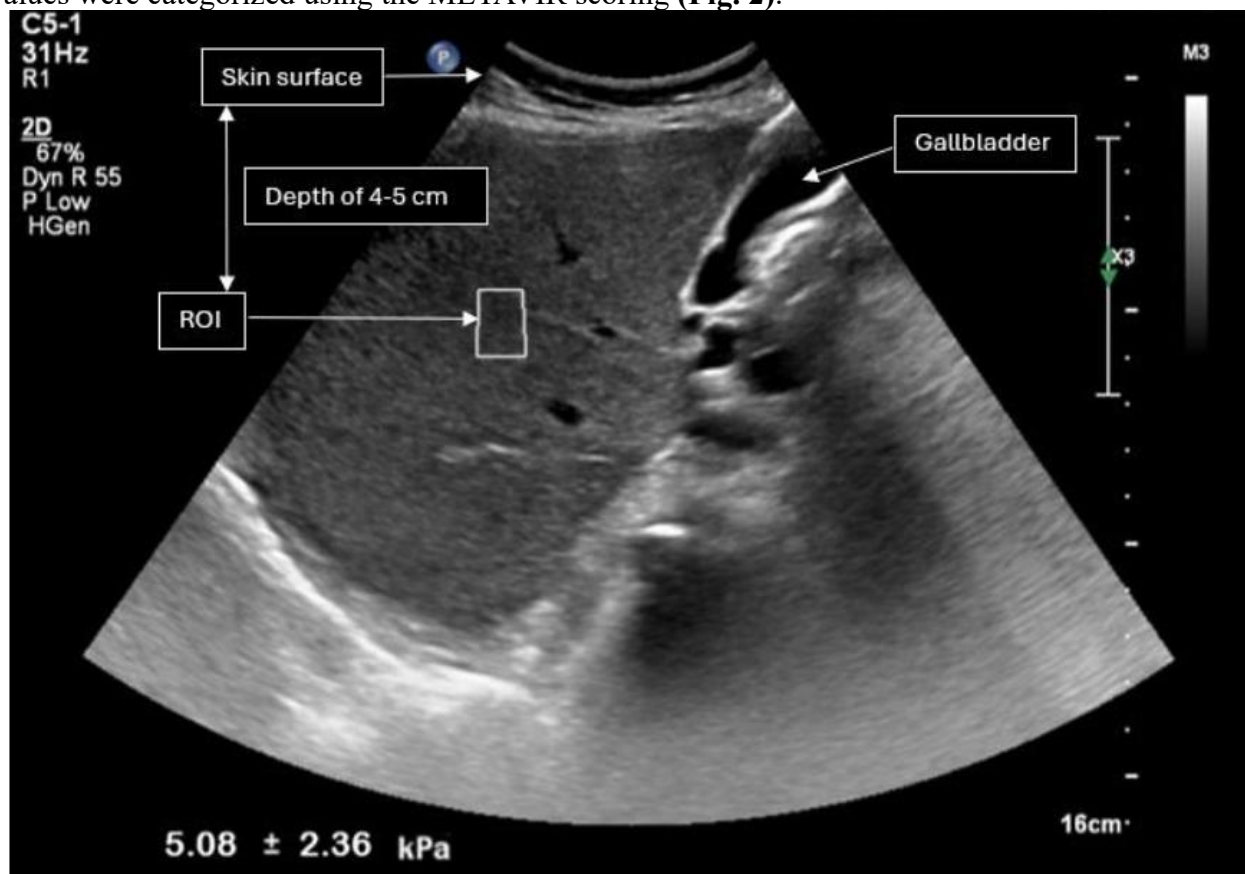


Figure 1 : Demonstration of placement of region of interest (ROI) while performing elastography.

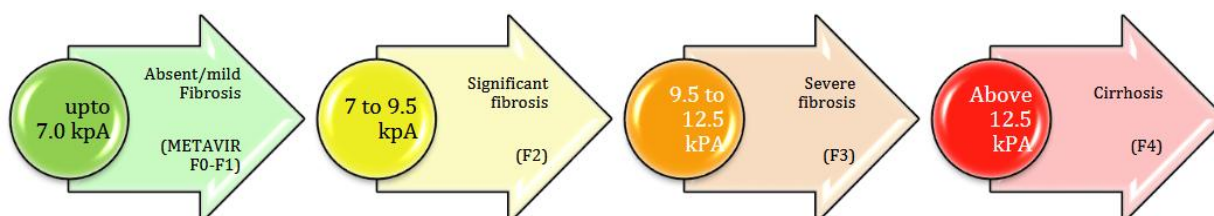


Figure 2 : Cut-off values of liver stiffness measured in kPa by elastography categorized by using METAVIR score⁶

Statistical Analysis

Data was analyzed using SPSS version 22. Continuous variables, such as liver stiffness values measured in kilopascals (kPa), were summarized using mean, median, and range. Categorical variables, including LI-RADS categories and METAVIR fibrosis stages, were expressed as frequencies and percentages.

To assess the relationship between METAVIR fibrosis stages and LI-RADS categories, Spearman's rank correlation coefficient was calculated. Spearman's rho (ρ) was used to determine the strength and direction of the association between these two ordinal variables. A p-value of less than 0.05 was considered statistically significant.

Additionally, a Chi-square test for association was done to evaluate the relationship between categorized liver stiffness levels (Low <9.5 kPa, Medium 9.5–12.5 kPa, and High >12.5 kPa) and LI-RADS categories. A p-value of less than 0.05 was considered statistically significant for this analysis as well.

Results

This study spanned 18 months (May 2023–November 2024). A total of 90 patients aged 18 and above underwent triple-phase CT. Of these, 39 were excluded based on exclusion criteria, leaving 51 patients for assessment using point shear wave elastography (**Fig. 3**).

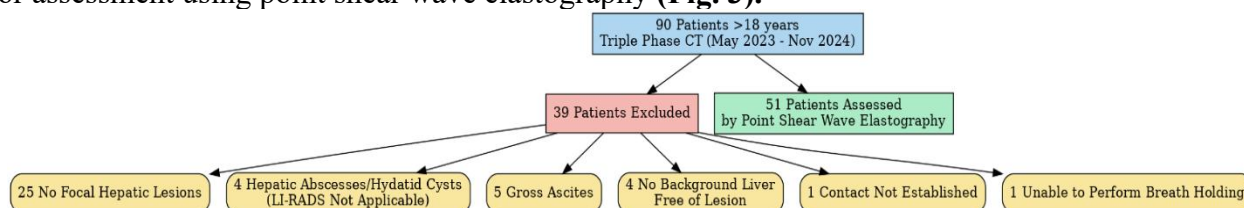


Figure 3 : Flowchart of excluded and included patients

The highest number of patients (55.77%) were aged 50-69 years (**Fig. 4**), aligning with the increased risk of liver lesions in middle-aged and older adults¹⁰. The study had more male participants (61.54%) than females (38.46%) (**Fig. 5**)

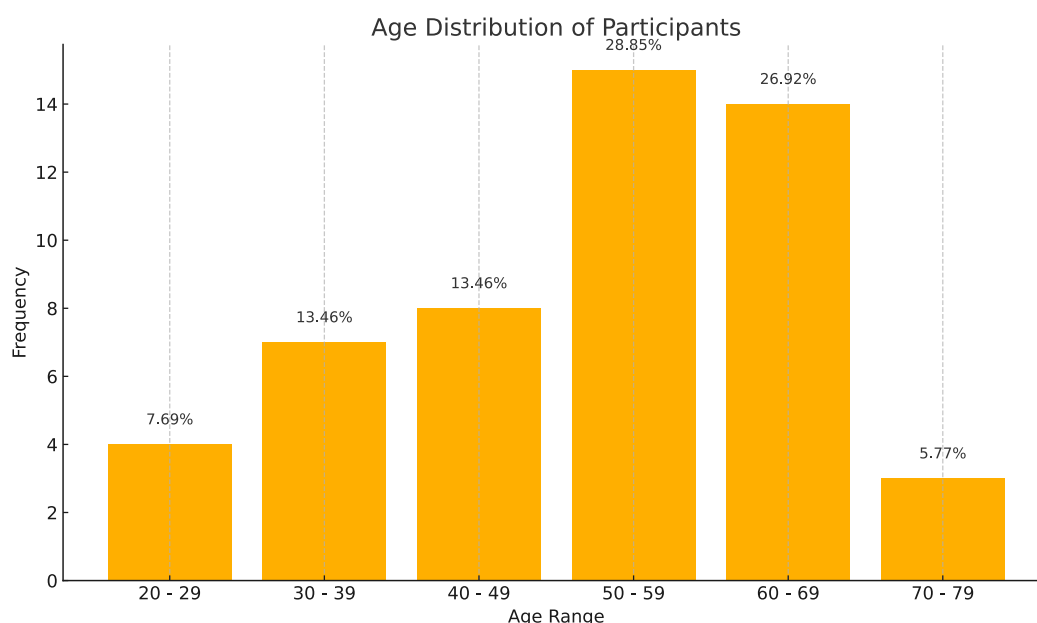


Figure 4 : Age distribution of the participants

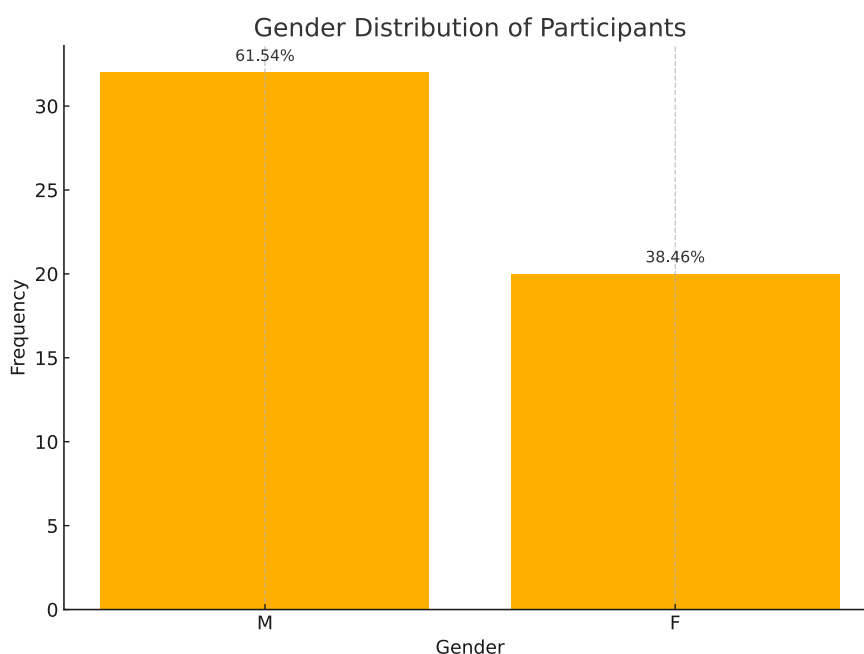


Figure 5 : Gender distribution of the participants

TPCT-detected hepatic lesions were characterized using the LI-RADS classification system. Benign (LR-1) and probably benign (LR-2) lesions were each seen in 5 cases (9.8%). Intermediate probability lesions (LR-3) and highly suspicious cases (LR-4) accounted for 7 cases each (13.72%). Definite hepatocellular carcinoma (LR-5) was found in 6 cases (11.76%). Malignant but non-HCC lesions (LR-M) were the most frequent, appearing in 11 cases (21.50%). Tumors with vascular invasion (LR-TIV) were seen in 10 cases (19.60%), indicating aggressive malignancy (**Fig. 6**).

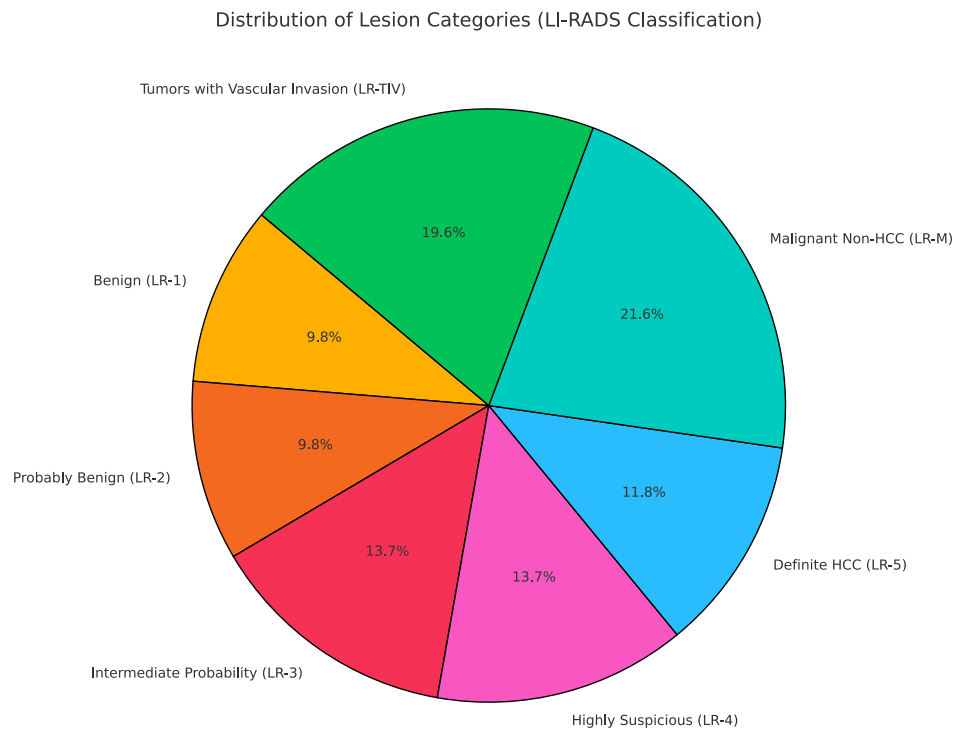


Figure 6 : Distribution of LIRADS categories of the lesions

Liver stiffness was measured using elastography and classified using the METAVIR scoring system. The most common stage was advanced cirrhosis (F4), found in 17 cases (33.33%). Mild or no fibrosis (F0-F1) was seen in 16 cases (31.37%). Significant fibrosis (F2) was observed in 10 cases (19.60%), while severe fibrosis (F3) was least common (15.68%). More than half of the patients (50.97%) had significant to advanced fibrosis (F2-F4).(**Fig. 7**).

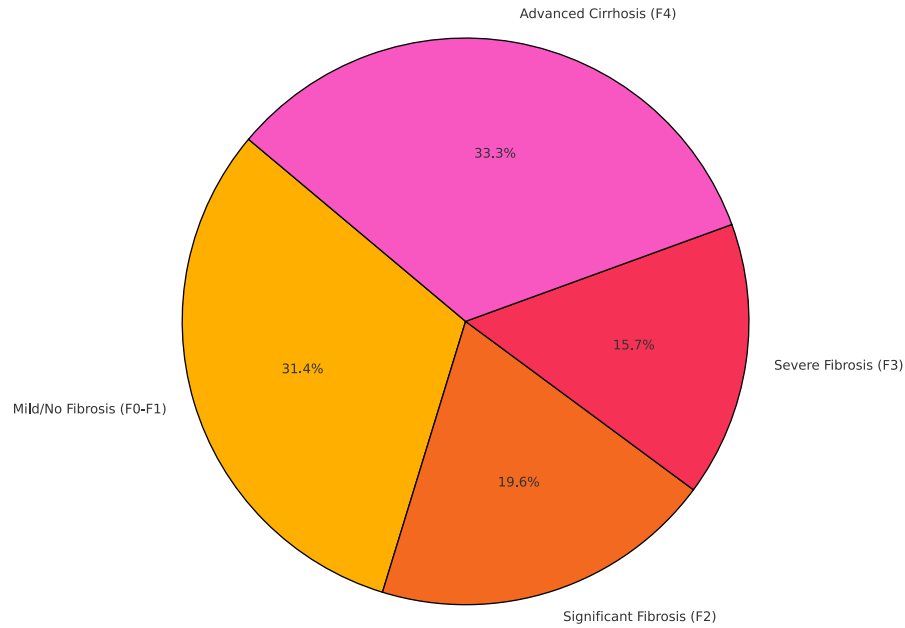


Figure 7 : Distribution of liver stiffness (METAVIR score)

The liver stiffness measurements assessed by elastography were tabulated across different LI-RADS categories (**Table 1**). Benign lesions (LR-1) and probably benign lesions (LR-2) demonstrated the lowest mean liver stiffness values, measuring 5.81 kPa and 6.84 kPa, respectively. Intermediate probability lesions (LR-3) and highly suspicious lesions (LR-4) showed higher mean stiffness values of 11.16 kPa and 11.21 kPa, respectively. Definite hepatocellular carcinoma (LR-5) exhibited a further increase in liver stiffness, with a mean value of 14.49 kPa and a median of 13.67 kPa. Malignant but non-HCC lesions (LR-M) demonstrated a mean stiffness of 11.01 kPa, with values ranging from 4.5 to 21.9 kPa, indicating considerable variability within this group. The highest liver stiffness measurements were observed in tumors with vascular invasion (LR-TIV), with a mean stiffness of 19.72 kPa and a median of 18.8 kPa, ranging from 10.9 to 28.3 kPa. (**Fig. 8**)

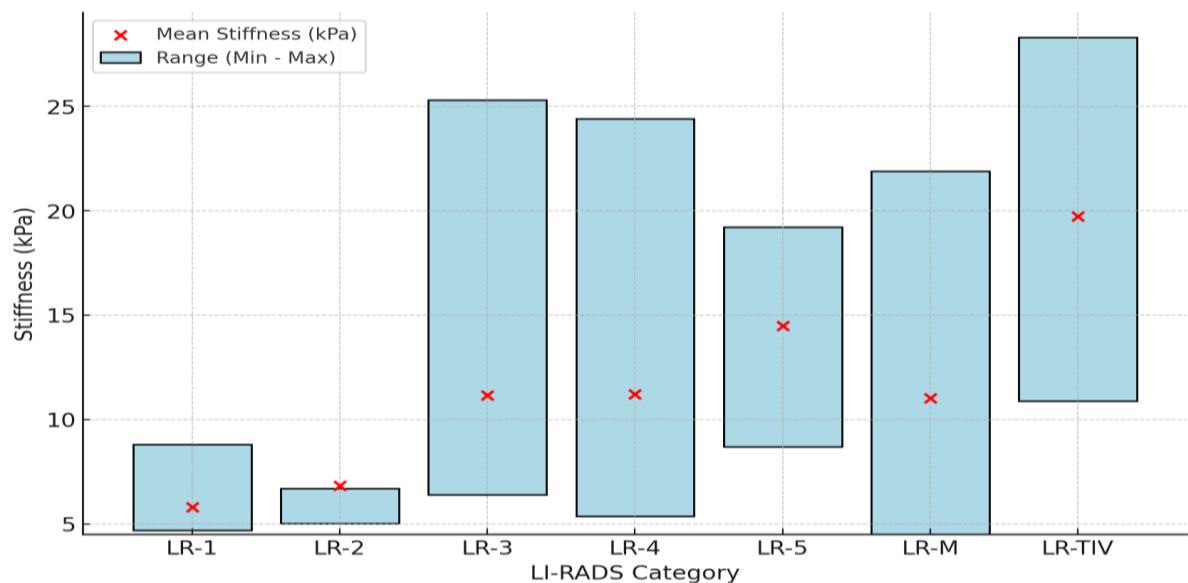


Figure 8 : Bar graph showing the relationship between LI-RADS categories and background liver stiffness measurements (kPa). The blue bars represent the range of liver stiffness values (minimum to maximum) within each LI-RADS category. The red "x" markers indicate the mean liver stiffness for each category. Notably, LR-TIV lesions demonstrate the highest mean stiffness and widest range, suggesting more advanced liver pathology. The trend indicates increasing stiffness correlating with higher LI-RADS categories.

LI-RADS	Count	Mean Stiffness (kPa)	Median Stiffness (kPa)	Range (kPa)
LR-1	5	5.81	5.8	4.69 - 8.8
LR-2	5	6.84	6.9	5.03 - 7.7
LR-3	7	11.16	7.7	6.4 - 25.3
LR-4	7	11.21	8.11	5.38 - 24.4
LR-5	6	14.49	13.67	8.7 - 19.21
LR-M	11	11.01	9.21	4.5 - 21.9
LR-TIV	10	19.72	18.8	10.9 - 28.3

Table 1. LI-RADS Categories Assessed by Triphasic CT (TPCT) and Corresponding Liver Stiffness Measurements by Elastography

A Chi-square test demonstrated a statistically significant association between CT LI-RADS categories and METAVIR categorized liver stiffness levels ($\chi^2 = 36.15$, $p = 0.00031$). Higher LI-RADS categories were more frequently associated with increased liver stiffness, suggesting a link between lesion suspicion level and background liver fibrosis severity.

Additionally, a Spearman's rank correlation was performed to evaluate the relationship between the ordinal LI-RADS categories and mean liver stiffness measured by elastography. A strong positive correlation was found ($\rho = 0.79$, $p = 0.036$), indicating that higher LI-RADS categories were associated with increased liver stiffness. **(Fig. 9)**

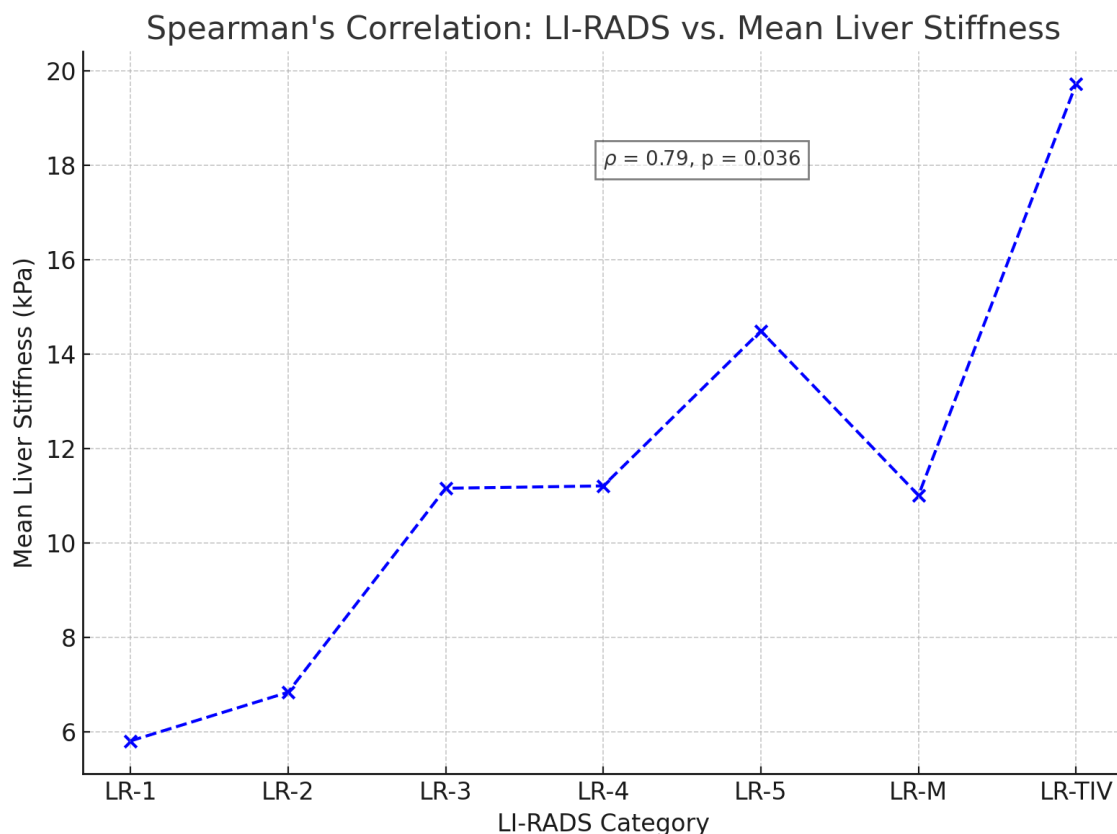


Figure 9 : Scatter plot illustrating the correlation between LI-RADS categories and mean liver stiffness. A strong positive correlation was observed (Spearman's $\rho = 0.79$, $p = 0.036$).

Discussion

This study investigated the correlation between elastography derived background liver stiffness and Triple Phase CT based LI-RADS categorization in patients with focal hepatic lesions. The majority of patients (55.77%) were in the age range of 50-69 years, consistent with the known prevalence of

liver malignancies in middle-aged and older adults¹¹. The lower number of cases in younger individuals suggests that liver lesions in this group are often incidental or occur secondarily to non-malignant processes¹². A higher proportion of male patients (61.54%) was observed compared to females (38.46%), which can be attributed to hormonal differences, higher alcohol consumption, and greater exposure to hepatotoxic agents. These factors contribute to the increased incidence of hepatocellular carcinoma (HCC) and other liver-related malignancies in men.¹³

Triple phase CT revealed a significant number of malignant lesions with a higher LIRADS category. LR-5 (11.76%), LR-M (21.50%), and LR-TIV (19.60%) categories represented a major portion of the cases. The presence of vascular invasion (LR-TIV) in 19.60% of cases highlights the aggressive nature of many liver malignancies. The proportion of LR-1 (9.80%) and LR-2 (9.80%) cases suggests that a smaller subset of patients had benign lesions, such as simple cysts and hemangiomas.

Liver stiffness measurements correlated with disease severity. Patients classified as LR-TIV had the highest mean stiffness (19.72 kPa), while those in LR-1 had the lowest (5.81 kPa). The most common fibrosis stage was F4 (33.33%), indicating that a significant number of patients had cirrhosis. Nearly half (50.97%) had moderate to severe fibrosis (F2-F4), suggesting a need for early intervention to prevent disease progression.

Spearman's rank correlation analysis demonstrated a strong, statistically significant positive correlation between liver stiffness and LI-RADS category ($\rho = 0.79$, $p = 0.036$). This suggests that as background liver stiffness increases, there is a corresponding increase in the LI-RADS category of the focal hepatic lesion, indicating a higher suspicion for malignancy. This correlation supports the hypothesis that advanced liver fibrosis, reflected by increased stiffness, may contribute to a hepatic microenvironment conducive to malignant transformation.

Furthermore, the Chi-square test for association between categorized liver stiffness levels (Low <9.5 kPa, Medium 9.5–12.5 kPa, High >12.5 kPa) and LI-RADS categories demonstrated a statistically significant association ($\chi^2 = 36.15$, $p = 0.00031$). Higher LI-RADS categories were significantly more common in patients with increased liver stiffness, reinforcing the potential role of elastography-derived liver stiffness as an adjunctive biomarker in the imaging-based evaluation of focal hepatic lesions.

Our findings are consistent with those reported by Li et al. (2021), who demonstrated that liver stiffness measurements obtained via ultrasound elastography improved the diagnostic performance of CEUS LI-RADS in detecting hepatocellular carcinoma. Similar to their conclusions, our study highlights a significant correlation between liver stiffness and LI-RADS categorization, reinforcing the role of elastography of the background liver as an adjunctive tool in the non-invasive assessment of focal hepatic lesions.⁸

However, when Chang et al. (2021) investigated the pathological considerations of CEUS LI-RADS, they demonstrated that while hepatic fibrosis stage did not significantly influence LI-RADS categorization, the histological grade of hepatocellular carcinoma (HCC) did. In their study, low-grade HCCs were more frequently classified as LR-5, whereas high-grade tumors were predominantly assigned to the LR-TIV category, reflecting their aggressive nature. In contrast, our study focused on liver stiffness measurements obtained through elastography as a non-invasive marker for hepatic fibrosis severity. We observed a significant correlation between increased liver stiffness and higher LI-RADS categories on TPCT, with LR-TIV lesions exhibiting the highest mean stiffness values.¹⁴

Limitations

The small sample size and single-center design reduce the generalizability of the findings, making it difficult to apply them to broader populations. A larger, multi-center study would provide more robust data. The absence of histopathological confirmation limits the ability to definitively classify lesions, as imaging and elastography findings alone may not always distinguish between benign and malignant cases¹⁵. Incorporating biopsy results in future research could improve diagnostic accuracy.

Conclusion

Our study's findings reflect that background liver stiffness can serve as an adjunctive biomarker for lesion assessment in the context of LI-RADS classification. The significant correlation with LI-RADS

classification suggests that elastography can enhance diagnostic accuracy, reduce the need for invasive biopsies, and aid in early detection of hepatic malignancies.

List of abbreviations :

CLD – Chronic Liver Disease

CT – Computed Tomography

HCC – Hepatocellular Carcinoma

LI-RADS – Liver Imaging Reporting and Data System

LR-TIV – LI-RADS category for Tumor in Vein

LR-M – LI-RADS category for malignant but non-HCC malignancy

METAVIR – Meta-analysis of Histological Data in Viral Hepatitis

TPCT – Triple-Phase Computed Tomography

Declarations

Ethics Approval and Consent to Participate

This study was approved by the Institutional Ethics Committee of Sharda University, Greater Noida, India. Written informed consent was obtained from all individual participants included in the study.

Consent for Publication

Written informed consent for publication of anonymized patient data and accompanying images was obtained from the patients included in this study.

Availability of Data and Materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing Interests

The authors declare that they have no competing interests.

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Authors' Contributions

V.D. - Responsible for patient recruitment, data acquisition, and image analysis, including performing and documenting elastography assessments. Conducted the data interpretation and statistical analysis under supervision. Drafted the initial version of the manuscript.

K.K. - Acted as the supervisor and principal investigator for the study. Oversaw the methodology and provided expert input into the interpretation of imaging findings and statistical analyses, and will be responsible for correspondence during peer review and publication.

V.G. - Provided overall guidance and conceptual support for the project. Contributed to reviewing the manuscript, offered critical insights into the interpretation of results, and ensured the methodological rigor of the study.

K.Ka. - Assisted with patient selection, data collection, and performing elastography assessments. Contributed to the statistical analysis and the creation of figures and tables, ensuring clear and accurate data visualization. Participated in proofreading and editing the manuscript and approved the final version.

All authors read and approved the final manuscript.

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