



Hepatic Artery Resistance Index as a Prognostic Marker in Liver Cirrhosis: A Case-Control Study

Bizhan Ahmadi^{1,2}, Faezeh Bagheri³, Ahmad Enhesari^{3,4}, Sarir Nazemi³, Motahareh Zaherara^{5,6}

¹Department of Gastroenterology, Afzalipour Hospital, School of Medicine, Kerman University of Medical Sciences, Kerman, Iran

²Clinical Research Unit, Afzalipour Hospital, Kerman University of Medical Sciences, Kerman, Iran

³Department of Radiology, Afzalipour Hospital, School of Medicine, Kerman University of Medical Sciences, Kerman, Iran

⁴Physiology Research Center, Institute of Basic and Clinical Physiology, School of Medicine, Kerman University of Medical Sciences, Kerman, Iran

⁵Department of Medical Basic Sciences, School of Medicine, Bam University of Medical Sciences, Bam, Iran

⁶Anatomy Department, School of Medicine, Kerman University of Medical Sciences, Kerman, Iran

*Corresponding Author: Motahareh Zaherara, Email: mzaherara@yahoo.com

Abstract

Introduction: Liver cirrhosis poses significant prognostic challenges, necessitating non-invasive tools like the hepatic artery resistance index (HARI) to assess disease severity. This study evaluated HARI's prognostic utility among cirrhotic patients in Iran.

Methods: In a case-control study conducted at Afzalipour Hospital in Kerman, Iran, in 2021, 25 patients with liver cirrhosis and 25 healthy controls were enrolled. We measured HARI, pulsatility index (PI), and peak systolic velocity (PSV) by Doppler ultrasound. Laboratory parameters (albumin, creatinine, INR, prothrombin time) and prognostic scores (Child-Pugh, MELD) were assessed. Data were analyzed using t-tests, ANOVA, and Pearson's correlations in SPSS version 25 ($P < 0.05$).

Results: Cirrhotic patients exhibited significantly higher HARI (0.81 ± 0.10 vs. 0.44 ± 0.10 , $P < 0.001$), PI (1.23 ± 0.20 vs. 1.03 ± 0.11 , $P < 0.001$), and PSV (102.16 ± 2.54 vs. 73.88 ± 5.80 cm/s, $P < 0.001$) than controls. HARI increased across Child-Pugh classes (A: 0.76 ± 0.04 , B: 0.81 ± 0.14 , C: 0.91 ± 0.02 , $P = 0.002$) and correlated moderately with MELD ($r = 0.52$, $P = 0.008$) and Child-Pugh scores ($r = 0.48$, $P = 0.015$). Albumin was lower (1.44 ± 0.49 vs. 3.56 ± 1.36 g/L, $P = 0.002$) and creatinine was higher (1.97 ± 0.97 vs. 1.24 ± 0.27 mg/dL, $P = 0.013$) in cases.

Conclusion: HARI is a promising non-invasive marker for cirrhosis prognosis, particularly in severe cases. Larger studies are needed to establish standardized thresholds.

Keywords: Hepatic artery, Prognosis, International Normalized Ratio, Liver cirrhosis, Ultrasonography, Doppler

Citation: Ahmadi B, Bagheri F, Enhesari A, Nazemi S, Zaherara M. Hepatic artery resistance index as a prognostic marker in liver cirrhosis: a case-control study. Journal of Kerman University of Medical Sciences 2026;33:4237. doi:10.34172/jkmu.4237

Received: November 3, 2025, **Accepted:** December 15, 2025, **ePublished:** June 14, 2026

Introduction

Liver cirrhosis, a chronic condition marked by progressive fibrosis and regenerative nodules, disrupts hepatic vasculature and increases portal pressure, often leading to liver failure (1, 2). Fibrosis erodes sinusoidal structures, creating shunts between hepatic arterial, portal, and venous systems, which exacerbate hemodynamic instability (3, 4). Accurate prognostication is critical for managing cirrhosis; nevertheless, it still presents significant challenges owing to the complexity of the disease's evolution. Child-Pugh score, a widely used prognostic tool, classifies patients into classes A, B, and C based on clinical and laboratory parameters, predicting one-year survival rates of approximately 100%, 80%, and 45%, respectively (5-7). The Model for End-Stage Liver Disease (MELD) score, which integrates serum creatinine, bilirubin, and INR, estimates three-month

mortality but overlooks complications like ascites (8, 9). Both tools have limitations, as minor changes in input variables can significantly alter outcomes, prompting exploration of alternative methods (10). Hemodynamic changes in liver circulation are central to cirrhosis complications, making non-invasive imaging techniques like Doppler ultrasound increasingly valuable (11). The hepatic artery resistance index (HARI), measured by Doppler ultrasound, reflects arterial resistance and may correlate with disease severity (12). Unlike portal vein assessments, which are confounded by portosystemic shunts, HARI directly evaluates arterial dynamics, offering a reliable marker (13). Studies suggest HARI increases with cirrhosis severity, but its prognostic utility remains underexplored, particularly in Iran (14, 15). This study aimed to assess HARI and its association with Child-Pugh and MELD scoring parameters in Iranian



cirrhotic patients. By comparing Doppler indices (HARI, PI, and PSV) and laboratory markers between cirrhotic and healthy individuals, we sought to explore the utility of HARI as a non-invasive prognostic tool, hypothesizing that its levels would be higher in individuals with cirrhosis and correlate with disease progression.

Methods

Study Framework and Ethical Approval

Our descriptive-analytical case-control study was conducted at Afzalipour Hospital, Kerman, Iran, in 2021, to investigate the association of hepatic artery resistance index (HARI) with prognostic factors in liver cirrhosis. Approval was obtained from the Ethics Committee of Kerman University of Medical Sciences (Ethical code: IR.KMU.AH.REC.1399.030), and informed consent was obtained from each participant before enrollment.

Participants

The study population comprised patients attending the gastroenterology clinic at Afzalipour Hospital. The case group included 25 patients with clinically or pathologically confirmed liver cirrhosis. The control group consisted of 25 healthy individuals without liver disease (16). Exclusion criteria were: cardiac, pulmonary, or vascular diseases; portal vein thrombosis detected by Doppler ultrasound; large liver masses compressing vessels; history of liver surgery or vascular interventions; use of vasoactive drugs (e.g., propranolol) or diuretics within 48 hours; dialysis; unwillingness to participate; or incomplete data (> 10%) (7,8).

Sample Size

The number of participants required for this study was estimated using data from an earlier study (11), which showed the variation in hepatic artery resistance index (HARI) between cirrhotic patients and healthy subjects using a two-tailed t-test for independent groups. The reported mean $\pm$ SD values were 0.82 ± 0.09 in the cirrhosis group and 0.70 ± 0.08 in the control group. Calculations for determining the required sample size were performed with G*Power software (version 3.1), considering $\alpha = 0.05$, $\beta = 0.80$ –1, and a Cohen's d effect size of 0.8.*

For each group, the sample size was calculated using the following formula:

$$n = \frac{2(\beta - 1Z\alpha / 2 - 1 + Z)^2}{d^2}$$

Substituting $\alpha/2 = 1.96$, $\beta = 0.84$, and $d = 0.8$ yields a sample size of approximately $n = 24.5$ per group. (17) Therefore, 25 participants were selected in each group, and an additional 10% was considered to compensate for the possibility of sample dropout.

Data Collection

Demographic data (age, gender, weight), clinical history (duration of illness, encephalopathy, treatment status), and medication use were recorded. Laboratory tests

measured serum bilirubin, albumin, prothrombin time, creatinine, and INR. A radiologist performed an abdominal ultrasound using a Philips G50 device with a 3–5 MHz curved probe, assessing liver morphology, ascites severity (mild, moderate, severe), and Doppler parameters: HARI, pulsatility index (PI), and peak systolic velocity (PSV). HARI was computed as (peak systolic velocity – end-diastolic velocity)/peak systolic velocity, and PI as (peak systolic velocity – end-diastolic velocity)/mean velocity. Each measurement was obtained in triplicate and averaged, using the ultrasound device's automatic calculation feature. Patients were assigned to Child-Pugh classes A, B, and C based on established clinical and laboratory criteria (18).

Statistical Analysis

Data were analyzed using SPSS version 25. Independent t-tests compared continuous variables (e.g., HARI, laboratory markers) (7) between the case and control groups. ANOVA assessed differences in Doppler parameters across Child-Pugh classes. Pearson's correlation coefficients were used to evaluate associations between HARI and prognostic scores (MELD, Child-Pugh). A threshold of $P < 0.05$ was used to determine statistical significance.

Results

This case-control study included 50 participants: 25 with liver cirrhosis (case group) and 25 healthy participants. The patient and control groups had mean ages of 59.64 ± 6.51 and 57.60 ± 5.61 years, respectively ($P = 0.280$). The gender distribution showed that 56% of patients and controls were female (52%; $P = 0.500$), suggesting no significant demographic differences between the groups.

Laboratory and Radiological Findings

Table 1 summarizes demographic, laboratory, and radiological characteristics. The case group exhibited significantly lower albumin (1.44 ± 0.49 vs. 3.56 ± 1.36 g/L, $P = 0.002$), higher creatinine (19) (1.97 ± 0.97 vs. 1.24 ± 0.27 mg/dL, $P = 0.013$), elevated INR (1.80 ± 0.84 vs. 1.04 ± 0.14 , $P = 0.023$), and shorter prothrombin time (3.80 ± 0.41 vs. 4.09 ± 0.51 s, $P = 0.005$) compared to the controls. Doppler parameters were significantly higher in the case group: HARI (0.81 ± 0.10 vs. 0.44 ± 0.10 , $P < 0.001$), PI (1.23 ± 0.20 vs. 1.03 ± 0.11 , $P < 0.001$), and PSV (102.16 ± 2.54 vs. 73.88 ± 5.80 cm/s, $P < 0.001$). The mean MELD score in the case group was 19.12 ± 10.03 , as well as the Child-Pugh score, which averaged 9.52 ± 3.61 . Ascites was present in 84% of cases (mild: 52%, moderate: 24%, severe: 8%). Child-Pugh classification (7) showed 68% in class A, 24% in class B, and 8% in class C.

Doppler Parameters by Child-Pugh Class

Table 2 presents Doppler parameters across Child-Pugh classes. HARI values were significantly elevated in Child-Pugh class C (0.91 ± 0.02) compared with class B (0.81 ± 0.14) and class A (0.76 ± 0.04), with a P value of 0.002. No significant differences were observed for PI (A: 1.23 ± 0.20 , B: 1.30 ± 0.22 , C: 1.17 ± 0.18 , $P = 0.110$) or PSV

Table 1. Demographic, Laboratory, and Radiological Characteristics

Variable	Case (N = 25)		Control (N = 25)		P value
	Mean	SD	Mean	SD	
Age (years)	59.64	6.51	57.60	5.61	0.280
Albumin (g/L)	1.44	0.49	3.56	1.36	0.002
Creatinine (mg/dL)	1.97	0.97	1.24	0.27	0.013
INR	1.80	0.84	1.04	0.14	0.023
Prothrombin time (s)	3.80	0.41	4.09	0.51	0.005
HARI	0.81	0.10	0.44	0.10	<0.001
PI	1.23	0.20	1.03	0.11	<0.001
PSV (cm/s)	102.16	2.54	73.88	5.80	<0.001
MELD	19.12	10.03	-	-	-
Child-Pugh score	9.52	3.61	-	-	-
Variable	Subgroup	Prevalence	%	Prevalence	%
Gender	Male	11	44	12	48
	Female	14	56	13	52
Ascites	Mild	13	52	-	-
	Moderate	6	24	-	-
	Severe	2	8	-	-
Child-Pugh	A	17	68	-	-
	B	6	24	-	-
	C	2	8	-	-

Table 2. Doppler Parameters by Child-Pugh Class

Variable	Child A (N = 11)		Child B (N = 7)		Child C (N = 7)		P value
	Mean	SD	Mean	SD	Mean	SD	
HARI	0.76	0.04	0.81	0.14	0.91	0.02	0.002
PI	1.23	0.20	1.30	0.22	1.17	0.18	0.110
PSV (cm/s)	103.32	2.45	102.10	2.47	101.60	1.50	0.820

(A: 103.32 ± 2.45 , B: 102.10 ± 2.47 , C: 101.60 ± 1.50 cm/s, $P = 0.820$).

Correlation Analysis

Pearson's correlation analysis demonstrated a moderate positive association between HARI and MELD scores ($r = 0.52$, $P = 0.008$) and between HARI and Child-Pugh scores ($r = 0.48$, $P = 0.015$) in this case group. No significant correlations were found for PI or PSV with prognostic scores ($P > 0.05$). HARI showed a significant negative association with albumin levels ($r = -0.45$, $P = 0.025$), suggesting an association with liver dysfunction severity.

Subgroup Analysis

Patients with ascites (84%) had higher HARI scores (0.83 ± 0.09) than those without (0.76 ± 0.05 ; $P = 0.045$). Severe ascites was associated with the highest HARI values (0.88 ± 0.03). Gender and age were not significantly associated with Doppler parameters ($P > 0.05$).

Discussion

This study employed a case-control design at Afzalipour Hospital, Kerman, Iran, in 2021, to examine HARI as a prognostic marker in 50 participants (25 with liver cirrhosis

and 25 controls). The cirrhosis group exhibited significantly higher HARI (0.81 ± 0.10 versus 0.44 ± 0.10 , $P < 0.001$), PI (1.23 ± 0.20 versus 1.03 ± 0.11 , $P < 0.001$), and PSV (102.16 ± 2.54 versus 73.88 ± 5.80 cm/s, $P < 0.001$) compared to the controls. Among Child-Pugh classes, HARI increased significantly from class A to C ($P = 0.002$), whereas PI and PSV did not differ significantly between groups ($P > 0.05$). The present findings align with prior research highlighting HARI's elevation in cirrhosis, driven by structural changes, such as sinusoidal capillarization and fibrosis, which increase arterial resistance (11, 13). Unlike portal vein measurements, which are affected by portosystemic shunts, HARI directly assesses arterial dynamics, making it a robust marker of cirrhosis severity (12, 19). Studies by Afif et al. (11) and Stulic et al. (12) showed significantly higher HARI values among cirrhotic patients, which correlated closely with Child-Pugh classification. Park et al. (14) also found that HARI increases with increasing MELD score, confirming its association with the severity of hepatic impairment, and Zhang et al. (15) observed similar increases in HARI, which is consistent with our results. Radiology texts also note HARI's diagnostic potential, though PI and PSV data are less consistent (8, 20). The significant correlation between HARI and Child-Pugh

class, particularly in class C, mirrors findings by Afif et al. (11) and suggests HARI's utility in stratifying disease severity. However, Elshaer et al. (13) observed that while HARI reliably discriminates cirrhotic from noncirrhotic livers, its sensitivity is reduced in patients with advanced portal hypertension, possibly due to vascular remodeling. Hirsch et al. (21) did not explore this association, thereby limiting comparisons. HARI has been identified by Mousa et al. (22) as a reliable indicator for evaluating liver fibrosis in non-alcoholic fatty liver disease. In the present study, a moderate correlation between HARI and MELD scores ($r=0.52$, $P=0.008$) further supports its prognostic value, aligning with the study by Park et al. (12). Recently, the study by Elaban et al. (2024) has indicated that Doppler ultrasound offers a useful assessment compared to shear wave elastography in patients with liver cirrhosis (23). Our findings support this finding and underscore the diagnostic and prognostic utility of HARI, notably when integrated with elastography. No significant correlations were found for PI or PSV, consistent with the limited discussion in the radiology literature (11, 13). This gap underscores the need for further research to clarify their roles. Overall, these studies reinforce the reliability of HARI as a noninvasive indicator of cirrhosis severity, support its inclusion alongside conventional scoring systems, and highlight the importance of standardized protocols. HARI's combination of non-invasiveness and cost-effectiveness supports its use in settings with constrained resources, including Iran. Its correlation with ascites severity ($P=0.045$) suggests additional clinical applications. However, the study's findings may not be widely generalizable due to the small sample size and single-center design. The lack of long-term follow-up restricts insights into HARI's predictive reliability. Variability in ultrasound measurements, influenced by operator expertise or device settings, may also affect results (24). Future studies should involve larger, multi-center cohorts to validate HARI's sensitivity, specificity, and predictive values. Longitudinal designs could assess their prognostic accuracy over time. Combining HARI with other non-invasive tools, such as transient elastography, may enhance diagnostic precision (25). Establishing standardized HARI thresholds would facilitate clinical adoption.

Our study has several limitations. First, the limited sample size ($n=50$) and single-center design may limit the generalizability of the findings. Second, the cross-sectional, case-control design precluded evaluation of longitudinal outcomes and predictive accuracy over time. Third, Doppler ultrasound measurements may vary depending on operator expertise, patient factors (e.g., ascites, body habitus), and device calibration. Additionally, this study did not include histopathological confirmation of fibrosis severity or integrate other non-invasive modalities such as elastography, which could strengthen diagnostic comparisons. Prospective multicenter investigations with expanded patient cohorts and the use of combined imaging techniques are recommended to confirm HARI's utility as a standardized prognostic marker.

Conclusion

Our results suggest that HARI is a straightforward, non-invasive, and economical approach for diagnosing liver cirrhosis and assessing prognosis, particularly in severe cases (Child-Pugh class C). Its significant correlations with Child-Pugh and MELD scores highlight its clinical potential. Larger, multicenter studies with extended follow-up are needed to establish standardized HARI thresholds that ensure optimal sensitivity, specificity, and predictive accuracy. Integrating HARI into routine cirrhosis management could improve patient outcomes in resource-limited settings.

Acknowledgements

The authors also appreciate the good cooperation of the radiological personnel of Afzalipour Hospital.

Authors' Contribution

Conceptualization: Bizhan Ahmadi, Ahmad Enhesari, Sarir Nazemi
Data Curation: Faezeh Bagheri
Formal Analysis: Bizhan Ahmadi, Motahareh Zaherara
Funding Acquisition: Bizhan Ahmadi, Ahmad Enhesari
Investigation: Bizhan Ahmadi, Ahmad Enhesari, Faezeh Bagheri
Methodology: Bizhan Ahmadi, Ahmad Enhesari
Project Administration: Bizhan Ahmadi, Ahmad Enhesari
Resources: Bizhan Ahmadi, Ahmad Enhesari, Faezeh Bagheri
Software: Motahareh Zaherara
Supervision: Bizhan Ahmadi, Sarir Nazemi
Validation: Faezeh Bagheri, Motahareh Zaherara
Visualization: Motahareh Zaherara
Writing—Original Draft: Faezeh Bagheri, Motahareh Zaherara

Competing Interests

The authors declare no conflict of interest.

Data Availability Statement

Due to ethical and privacy restrictions related to patient clinical data from Afzalipour Hospital, the datasets for hepatic artery resistive index measurements in cirrhotic patients cannot be shared publicly. De-identified data may be available from the corresponding author upon reasonable request and with approval of the Ethics Committee.

Ethical Approval

The Ethics Committee of Kerman University of Medical Sciences approved this study (Ethical code: [IR.KMU.AH.REC.1399.030](#)). Informed consent was obtained from all participants.

Funding

This study was self-funded by the authors and received no external financial support from any funding organization.

References

1. Ginès P, Krag A, Abraldes JG, Solà E, Fabrellas N, Kamath PS. Liver cirrhosis. *Lancet* 2021;398(10308):1359-76. doi:[10.1016/S0140-6736\(21\)01374-X](#)
2. Pinzani M. Pathophysiology of liver fibrosis. *Dig Dis* 2015;33(4):492-7. doi:[10.1159/000374096](#)
3. Di Bisceglie AM, Teckman J. Liver disease due to alpha-1 antitrypsin deficiency: are we surprised that it is more complex than we thought? *Hepatology* 2019;70(1):5-7. doi:[10.1002/hep.30694](#)
4. DellaVolpe J, Kim M, Bleck TP, Al-Khafaji A. Cerebrovascular physiology in liver disease. In: Nanchal R, Subramanian R, eds. *Hepatic Critical Care*. Cham: Springer International Publishing; 2018. p. 59-71. doi:[10.1007/978-3-319-66432-3_6](#)
5. Durand F, Valla D. Assessment of the prognosis of cirrhosis: Child-Pugh versus MELD. *J Hepatol* 2005;42 Suppl 1: S100-7.

- doi:[10.1016/j.jhep.2004.11.015](https://doi.org/10.1016/j.jhep.2004.11.015)
6. Peng Y, Qi X, Dai J, Li H, Guo X. Child-Pugh versus MELD score for predicting the in-hospital mortality of acute upper gastrointestinal bleeding in liver cirrhosis. *Int J Clin Exp Med* 2015;8(1):751-7.
 7. Abstracts of the 26th Annual Conference of APASL, February 15-19, 2017, Shanghai, China. *Hepatol Int* 2017;11(Suppl 1):1-1093. doi:[10.1007/s12072-016-9783-9](https://doi.org/10.1007/s12072-016-9783-9)
 8. Vivarelli M, Montalti R, Risaliti A. Multimodal treatment of hepatocellular carcinoma on cirrhosis: an update. *World J Gastroenterol* 2013;19(42):7316-26. doi:[10.3748/wjg.v19.i42.7316](https://doi.org/10.3748/wjg.v19.i42.7316)
 9. Kamath PS, Kim WR. The model for end-stage liver disease (MELD). *Hepatology* 2007;45(3):797-805. doi:[10.1002/hep.21563](https://doi.org/10.1002/hep.21563)
 10. Kim WK, Bae KH, Lee SC, Oh KJ. The latest insights into adipokines in diabetes. *J Clin Med* 2019;8(11):1874. doi:[10.3390/jcm8111874](https://doi.org/10.3390/jcm8111874)
 11. Afif AM, Chang JP, Wang YY, Lau SD, Deng F, Goh SY, et al. A sonographic Doppler study of the hepatic vein, portal vein and hepatic artery in liver cirrhosis: correlation of hepatic hemodynamics with clinical Child-Pugh score in Singapore. *Ultrasound* 2017;25(4):213-21. doi:[10.1177/1742271x17721265](https://doi.org/10.1177/1742271x17721265)
 12. Stulic M, Culafic D, Obrenovic R, Jankovic G, Alempijevic T, Lalosevic MS, et al. The clinical importance of cystatin C and hepatic artery resistive index in liver cirrhosis. *Medicina (Kaunas)* 2018;54(3):37. doi:[10.3390/medicina54030037](https://doi.org/10.3390/medicina54030037)
 13. Elshaer EM, Khater HM, Yousief AF. Role of colour Doppler ultrasound in the diagnosis and grading of liver cirrhosis compared with transient elastography (FibroScan). *Benha J Appl Sci* 2020;5(1 Pt 1):67-74.
 14. Park HS, Desser TS, Jeffrey RB, Kamaya A. Doppler ultrasound in liver cirrhosis: correlation of hepatic artery and portal vein measurements with Model for End-Stage Liver Disease score. *J Ultrasound Med* 2017;36(4):725-30. doi:[10.7863/ultra.16.03107](https://doi.org/10.7863/ultra.16.03107)
 15. Zhang L, Yin J, Duan Y, Yang Y, Yuan L, Cao T. Assessment of intrahepatic blood flow by Doppler ultrasonography: relationship between the hepatic vein, portal vein, hepatic artery and portal pressure measured intraoperatively in patients with portal hypertension. *BMC Gastroenterol* 2011;11:84. doi:[10.1186/1471-230x-11-84](https://doi.org/10.1186/1471-230x-11-84)
 16. Prystupa A, Błażewicz A, Kiciński P, Sak JJ, Niedzialek J, Zaluska W. Serum concentrations of selected heavy metals in patients with alcoholic liver cirrhosis from the Lublin region in eastern Poland. *Int J Environ Res Public Health* 2016;13(6):582. doi:[10.3390/ijerph13060582](https://doi.org/10.3390/ijerph13060582)
 17. Yadav S, Naithani D, Nautiyal N, Singh S. Effect of crystalloid coloadng speed on hemodynamics in patient undergoing elective LSCS under spinal anaesthesia: a randomized control trial. *Indian J Clin Anaesth* 2025;12(2):198-206. doi:[10.18231/ijca.2025.034](https://doi.org/10.18231/ijca.2025.034)
 18. Jack D. Highlights from the 13th European congress of clinical microbiology and infectious diseases in Glasgow, Scotland, May 10-13, 2003. The complex world of infectious diseases. *Drug News Perspect* 2003;16(6):399-401.
 19. Tanaka A. Emerging novel treatments for autoimmune liver diseases. *Hepatol Res* 2019;49(5):489-99. doi:[10.1111/hepr.13347](https://doi.org/10.1111/hepr.13347)
 20. Rumack CM, Levine D. *Diagnostic Ultrasound E-Book*. Elsevier Health Sciences; 2023.
 21. Hirsch B, Whittington KD, Walker J. Mentoring in radiologic science. *J Med Imaging Radiat Sci* 2020;51(3):354-7. doi:[10.1016/j.jmir.2020.05.008](https://doi.org/10.1016/j.jmir.2020.05.008)
 22. Mousa N, El-Eraky A, Arafa M, Elalfy H, Farag R, Abdel-Razik A, et al. Value of hepatic artery resistive index in evaluation of liver fibrosis related to non-alcoholic fatty liver diseases. *Med J Viral Hepat* 2023;7(2):1-8. doi:[10.21608/mjvh.2023.296888](https://doi.org/10.21608/mjvh.2023.296888)
 23. Ellaban HS, Afify SA, Abdelgawad MS. Doppler ultrasound compared to shear wave elastography for assessment of liver cirrhosis. *Egypt J Intern Med* 2024;36(1):61. doi:[10.1186/s43162-024-00320-w](https://doi.org/10.1186/s43162-024-00320-w)
 24. Berzigotti A, Piscaglia F. Ultrasound in portal hypertension--part 1. *Ultraschall Med* 2011;32(6):548-71. doi:[10.1055/s-0031-1281856](https://doi.org/10.1055/s-0031-1281856)
 25. Tapper EB, Loomba R. Noninvasive imaging biomarker assessment of liver fibrosis by elastography in NAFLD. *Nat Rev Gastroenterol Hepatol* 2018;15(5):274-82. doi:[10.1038/nrgastro.2018.10](https://doi.org/10.1038/nrgastro.2018.10)