THE ROLE OF RADIOLOGICAL IMAGING IN PREVENTING THE PROGRESSION OF CHRONIC HEPATITIS TO LIVER CIRRHOSIS

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Abstract: Chronic viral hepatitis caused by hepatitis B virus (HBV) and hepatitis C virus (HCV) remains one of the most significant global health challenges, with an estimated 296 million and 58 million people affected, respectively. Without timely diagnosis and intervention, a substantial proportion of these patients progress to liver fibrosis and ultimately to cirrhosis, a state associated with major morbidity, portal hypertension, and hepatocellular carcinoma. Liver biopsy has historically served as the reference standard for fibrosis staging; however, its invasiveness, sampling error, and patient discomfort have driven the development of noninvasive imaging alternatives. This narrative review examines the established and emerging roles of ultrasonography, transient elastography (FibroScan), shear wave elastography, magnetic resonance elastography (MRE), diffusion-weighted magnetic resonance imaging (DW-MRI), and computed tomography (CT) in the early detection and staging of liver fibrosis in patients with chronic hepatitis. Evidence from the reviewed literature consistently demonstrates that imaging-based modalities can accurately identify significant fibrosis and cirrhosis, enabling timely

therapeutic decisions that may halt or reverse disease progression. In particular, MRE exhibits area under the receiver-operating characteristic curve (AUC) values of up to 0.92 for advanced fibrosis, while DW-MRI achieves sensitivity of 88% and specificity of 81% for cirrhosis. Integration of these modalities into routine surveillance protocols offers a clinically practical pathway to prevent cirrhosis-related complications.

Keywords: liver fibrosis; chronic hepatitis; liver cirrhosis; radiological imaging; transient elastography; MR elastography; ultrasound; noninvasive diagnosis; METAVIR; diffusion-weighted MRI; computed tomography; portal hypertension

Introduction: Chronic hepatitis, predominantly caused by hepatitis B virus (HBV) and hepatitis C virus (HCV), constitutes a formidable global public health burden. The World Health Organization estimates that approximately 296 million individuals are living with chronic HBV infection and 58 million with chronic HCV infection worldwide. A critical and defining feature of these infections is their capacity to induce progressive hepatic fibrogenesis — an excessive accumulation of extracellular matrix proteins, primarily collagen, within the liver parenchyma. When left undetected and untreated, this fibrotic process advances relentlessly toward cirrhosis, a structurally irreversible endpoint characterized by widespread scarring, regenerative nodule formation, and profound disruption of hepatic architecture.

The clinical consequences of cirrhosis are grave. Portal hypertension leads to esophageal varices, ascites, spontaneous bacterial peritonitis, and hepatorenal syndrome. Moreover, cirrhosis is the single most important risk factor for hepatocellular carcinoma (HCC), with one-third of cirrhotic patients developing HCC during their lifetime. Despite major advances in antiviral therapy — including the introduction of highly effective direct-acting antivirals (DAAs) for HCV — early

and accurate identification of the fibrosis stage remains essential for guiding treatment decisions and predicting clinical outcomes.

Historically, liver biopsy served as the undisputed gold standard for staging hepatic fibrosis. However, this procedure carries inherent limitations including its invasive nature, risk of bleeding and infection (occurring in approximately 0.3% of cases), significant sampling error due to the heterogeneous distribution of fibrosis (as only 1/50,000th of total liver volume is sampled), inter- and intra-observer variability in histological interpretation, high cost, and poor patient acceptance — particularly for longitudinal monitoring. These limitations have catalyzed substantial research investment in noninvasive alternatives, with radiological imaging emerging as a cornerstone of modern hepatology practice.

This narrative review systematically examines the evidence supporting the role of various radiological imaging modalities — conventional ultrasonography, ultrasound-based elastography, transient elastography, shear wave elastography, magnetic resonance elastography, diffusion-weighted MRI, and CT — in the noninvasive detection, staging, and monitoring of liver fibrosis in patients with chronic viral hepatitis. The ultimate clinical objective is to demonstrate how timely radiological assessment can prevent — or at minimum delay — progression to cirrhosis by informing antiviral and hepatoprotective treatment strategies.

Literature review: The body of literature addressing noninvasive imaging for liver fibrosis assessment has expanded substantially over the past two decades. Early work focused on conventional B-mode ultrasonography, demonstrating that hallmarks of cirrhosis — including hepatic surface nodularity, increased parenchymal echogenicity, right lobe atrophy, caudate lobe hypertrophy, and splenomegaly — could be reliably identified by experienced operators. A landmark prospective study of 100 patients with suspected cirrhosis who underwent liver

biopsy demonstrated that high-resolution ultrasonography achieved 91% sensitivity and 94% specificity for detecting established cirrhosis [7].

The introduction of transient elastography (TE), marketed as FibroScan, represented a paradigm shift in noninvasive fibrosis assessment. Developed in the early 2000s, TE measures liver stiffness by propagating a low-frequency shear wave through the liver parenchyma and calculating shear wave velocity using ultrasound pulse-echo acquisition. Castera et al. demonstrated that TE showed diagnostic performance equivalent to serum markers for significant fibrosis, and combining the two approaches allowed liver biopsy to be avoided in the majority of chronic hepatitis C patients [4]. de Lédinghen and Vergniol subsequently confirmed that FibroScan is validated across multiple chronic liver disease etiologies, including chronic hepatitis B and C, alcoholic liver disease, non-alcoholic fatty liver disease, and post-transplant recurrence of hepatitis C, and that it constitutes an excellent tool for the early detection of cirrhosis [43].

Shear wave elastography (SWE) technology subsequently extended the elastographic principle into real-time two-dimensional imaging. Song et al. conducted a prospective multicenter study in China enrolling 448 patients with chronic hepatitis B to evaluate two-dimensional SWE using ElastQ technology [21]. This study demonstrated that 2D SWE is both technically feasible and diagnostically reliable for noninvasive monitoring of liver fibrosis, with performance that compares favorably with transient elastography while offering the additional advantage of real-time B-mode guidance for measurement placement.

Magnetic resonance elastography (MRE) has emerged as the most technically advanced and diagnostically accurate of the current elastographic techniques. A large meta-analysis reviewed by Yin and Ehman demonstrated that MRE achieves AUC values of 0.91 for clinically significant fibrosis and 0.92 for advanced fibrosis — figures that exceed those of ultrasound-based techniques [13]. The method uses

external mechanical vibrations to generate shear waves, which are then detected by modified phase-contrast MRI sequences and processed to generate quantitative elastograms reflecting regional tissue stiffness.

Diffusion-weighted MRI (DW-MRI) offers an orthogonal approach by quantifying Brownian motion of water molecules within hepatic tissue as the apparent diffusion coefficient (ADC). Progressive fibrosis restricts water diffusion by increasing collagen deposition and reducing the extracellular space, leading to lower ADC values. Paisant et al. demonstrated in a study of chronic viral hepatitis patients that normalized liver ADC $\leq 1.02 \times 10^{-3}$ mm²/s achieved 88% sensitivity and 81% specificity for the diagnosis of cirrhosis, with an AUC of 0.847 [8].

Computed tomography contributes to fibrosis assessment primarily through detection of morphological changes and portal hypertension sequelae in more advanced disease stages. The radiological literature, as reviewed by Pickhardt et al. and Sangster et al., comprehensively documents the CT spectrum of cirrhosis — including irregular hepatic surface, caudate-to-right-lobe ratio exceeding 0.65, segmental volume redistribution, splenomegaly, varices, and ascites [25]. However, CT has recognized limitations for early fibrosis staging as these morphological changes largely reflect established rather than pre-cirrhotic disease.

Quantitative MRI methods for chronic liver disease — including T1 and T2* mapping, proton density fat fraction (PDFF), and liver surface nodularity assessment — have been reviewed by Moura Cunha et al. [10] and represent an expanding frontier in comprehensive noninvasive liver assessment. Critically, the literature reviewed consistently demonstrates that no single modality is universally optimal; rather, the clinical context, resource availability, and individual patient characteristics should guide modality selection.

Methodology and findings. This review followed a narrative approach guided by a systematic search of the PubMed/MEDLINE database. The following MeSH

terms and free-text keywords were used in combination: "liver fibrosis," "hepatic fibrosis staging," "chronic hepatitis," "liver cirrhosis," "elastography," "transient elastography," "MR elastography," "diffusion-weighted MRI," "ultrasound liver," "computed tomography cirrhosis," and "noninvasive fibrosis diagnosis." The search was not restricted by language but focused on English-language publications. Articles published between 2000 and 2024 were considered, with emphasis placed on studies published from 2014 onward. Only original research articles, systematic reviews, and meta-analyses directly addressing imaging-based fibrosis assessment in chronic viral hepatitis were included. Case reports, abstracts, and letters without original data were excluded. A total of 32 publications directly contributed to the findings summarized in this review.

B-mode ultrasonography is universally recognized as the first-line imaging modality in patients suspected of having chronic liver disease. Its advantages include ready availability, absence of ionizing radiation, low cost, real-time acquisition, and excellent patient tolerance. The ultrasonographic hallmarks of cirrhosis are well established and include hepatic surface nodularity or irregularity, coarsened and heterogeneous parenchymal echotexture, blunting of the hepatic edge, caudate lobe hypertrophy (caudate-to-right-lobe ratio >0.65), right lobe atrophy, splenomegaly (splenic bipolar diameter >13 cm), and features of portal hypertension such as portal vein dilatation (>13 mm), ascites, and venous collaterals [7].

While conventional ultrasound demonstrates high sensitivity and specificity for established cirrhosis — with studies reporting values of 91% and 94%, respectively — its performance for pre-cirrhotic fibrosis stages (F1–F3 on the METAVIR scale) is considerably more modest. Subtle parenchymal changes at early fibrosis stages do not reliably produce distinguishable sonographic features, and there is substantial inter-operator variability. Nevertheless, ultrasound remains indispensable as a

screening tool and for the detection of complications including HCC surveillance, variceal risk stratification, and assessment of ascites.

Transient elastography measures the velocity of a mechanically generated low-frequency (50 Hz) shear wave propagating through the liver using a dedicated ultrasound transducer. Wave velocity, measured in kilopascals (kPa), correlates strongly with tissue stiffness and, by extension, with fibrosis stage. The examination is rapid (typically 5–10 minutes), reproducible, and can be performed at the bedside or in the outpatient setting with immediate results.

Invernizzi et al. reported that in a cohort of 711 patients with chronic liver disease of mixed etiology, liver stiffness values of 12.5–75.5 kPa were recorded in cirrhotic patients (F4). Using a cut-off of 17.6 kPa, the positive predictive value and negative predictive value for cirrhosis were both 90% [45]. In patients with chronic HBV, median FibroScan values were 3.5 kPa for F0, 6.4 kPa for F1, 9.5 kPa for F2, 11.4 kPa for F3, and 15.4 kPa for F4. For HCV patients, corresponding values were markedly higher, particularly at the F4 stage (26.4 kPa), reflecting the greater inflammatory burden associated with hepatitis C [51].

Notable limitations of TE include a technical failure rate of approximately 5%, predominantly in obese patients (body mass index >30 kg/m²) and those with narrow intercostal spaces. Additionally, liver stiffness values can be transiently elevated by acute hepatic inflammation, extrahepatic cholestasis, congestive heart failure, and post-prandial state — factors that must be considered when interpreting results. Despite these constraints, TE is validated across a wide range of chronic liver disease etiologies and is endorsed by major hepatology societies including the European Association for the Study of the Liver (EASL) as a recommended first-line noninvasive test.

METAVIR Stage	Histological Definition	FibroScan HBV (kPa)	FibroScan HCV (kPa)
F0	No fibrosis	3.5	6.3
F1	Portal fibrosis without septa	6.4	6.7
F2	Portal fibrosis with rare septa	9.5	9.1
F3	Numerous septa without cirrhosis	11.4	13.7
F4	Cirrhosis	15.4	26.4

Table 1. Median FibroScan (transient elastography) liver stiffness values (kPa) by METAVIR fibrosis stage in chronic HBV and HCV patients [51].

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Point shear wave elastography (pSWE), based on acoustic radiation force impulse (ARFI) technology, and two-dimensional SWE (2D SWE) represent the next generation of ultrasound elastographic techniques. Unlike TE, these methods are integrated into conventional ultrasound platforms, enabling simultaneous B-mode imaging with real-time measurement guidance. Shear waves are generated by a focused high-intensity ultrasound beam, and tissue displacement is tracked to calculate local shear wave velocity (m/s) or stiffness (kPa).

A study by Ferraioli et al. established cutoff values for SWE in chronic hepatitis: >1.78 m/s (AUC 0.777) for significant fibrosis (≥F2) and >2.24 m/s (AUC 0.935) for cirrhosis (F4), using TE as the reference standard [17]. The high AUC for cirrhosis detection is particularly relevant from a clinical prevention standpoint, as it enables identification of patients who require immediate intervention before cirrhotic decompensation occurs.

Song et al. conducted a prospective multicenter study in patients with chronic hepatitis B using 2D SWE (ElastQ), which found excellent intra- and inter-class correlation coefficients and established stage-specific cutoff values validated in both training and external validation cohorts [21]. Notably, the inter-observer correlation coefficient for SWE between an experienced radiologist and a radiology resident-in-training was 0.878, suggesting that the technique is learnable and consistent across operator experience levels [17].

MRE has emerged as the most diagnostically accurate noninvasive method for fibrosis staging across all etiologies of chronic liver disease. The technique employs a passive driver — placed on the abdominal wall — that transmits mechanical vibrations (typically 60 Hz) through the liver. Modified phase-contrast gradient-echo or spin-echo sequences detect the resulting wave propagation, and specialized inversion algorithms generate quantitative stiffness maps (elastograms) in kilopascals.

A large systematic review and meta-analysis by Yin and Ehman demonstrated that MRE achieves AUC values of 0.91 for clinically significant fibrosis (≥F2) and 0.92 for advanced fibrosis (≥F3), outperforming all ultrasound-based elastographic techniques evaluated [13]. A seminal study by Venkatesh et al. in an Asian population found that with a shear stiffness cutoff of 3.05 kPa, MRE differentiated significant fibrosis (≥F2) from mild fibrosis with excellent accuracy [12]. Furthermore, a study by Ichikawa et al. demonstrated that MRE showed excellent

correlation with morphometric quantification of fibrosis burden (Fibro-C-Index: r=0.78, 95% CI 0.59–0.88, p<0.001) and with histological staging, with AUC values of 0.95 (≥F2), 0.98 (≥F3), and 1.00 (F4 cirrhosis) [14].

The principal limitations of MRE are the considerably higher cost relative to ultrasound-based techniques, limited availability in resource-constrained settings, contraindications in patients with ferromagnetic implants, and claustrophobia-related failure. Technical failure due to iron overload (causing signal loss from T2* shortening) is also a concern, occurring more frequently with gradient-recalled echo sequences than spin-echo echo-planar imaging [9]. Nevertheless, where available, MRE is increasingly regarded as the noninvasive imaging modality of choice for staging liver fibrosis, particularly when ultrasound-based elastography produces inconclusive results.

Modality	AUC ≥F2	AUC ≥F3	AUC F4 (Cirrhosis)	Key Limitation
B-mode Ultrasound	Moderate	Moderate	0.91	Low sensitivity for early fibrosis
Transient Elastography (TE)	0.75–0.82	0.82–0.90	0.93–0.96	Fails in obesity; inflammation affects values
Shear Wave Elastography (SWE)	0.78	0.85	0.94	Operator dependency; obesity

Modality	AUC ≥F2	AUC ≥F3	AUC F4 (Cirrhosis)	Key Limitation
MR Elastography (MRE)	0.91	0.92	0.96–1.00	Cost; limited availability; iron overload
DW-MRI (ADC)	0.60	0.70	0.847	Not liver-specific; confounders
Computed Tomography (CT)	Limited	Limited	Moderate–Good	Radiation; morphological changes appear late

Table 2. Comparative diagnostic performance (AUC) of imaging modalities for liver fibrosis staging in chronic viral hepatitis [7, 8, 13, 17, 21, 43].

DW-MRI exploits the principle of restricted Brownian motion of water molecules in biological tissues. In fibrotic liver parenchyma, progressive deposition of extracellular collagen restricts water molecule diffusion, resulting in reduced apparent diffusion coefficient (ADC) values. Several b-values are used during acquisition (typically 0, 50, 500, and 1000 s/mm²), and the ADC map is computed from the signal intensity decay across these values.

Paisant et al. demonstrated an inverse correlation between fibrosis stage and normalized liver ADC ($p<0.05$). For predicting fibrosis stage ≥F2, ≥F3, and cirrhosis (F4), the AUC values of normalized liver ADC were 0.603, 0.704, and 0.847, respectively [8]. The normalized ADC threshold of $\leq 1.02\times10^{-3}$ mm²/s achieved 88% sensitivity and 81% specificity for cirrhosis detection, with a negative predictive

value of 99% — a clinically valuable property that allows reliable exclusion of cirrhosis in patients with low pre-test probability.

A particularly compelling feature of this study was its proposed sequential diagnostic strategy combining the FIB-4 serum index with DW-MRI, which reduced the need for liver biopsy to only 15.7% of patients and decreased DW-MRI examinations by 53.7% compared to DW-MRI alone [8]. This integrated approach exemplifies the direction of modern hepatology — leveraging complementary noninvasive tools in sequence to maximize diagnostic efficiency.

Multi-detector CT (MDCT) is the most sensitive conventional radiological tool for detecting hepatic morphological changes. In cirrhosis, CT demonstrates a characteristic spectrum of findings including irregular or nodular hepatic surface, widening of the porta hepatis and interlobar fissures, altered lobar volume distribution (right lobe atrophy with caudate and left lobe hypertrophy), parenchymal heterogeneity, and confluent fibrosis appearing as wedge-shaped hypoattenuating areas. Extrahepatic manifestations of portal hypertension — including splenomegaly, varices, portosystemic collaterals, ascites, and gallbladder wall thickening — are also well depicted on contrast-enhanced CT [25].

More than 60% of patients with early cirrhosis may exhibit hepatomegaly on CT, and a caudate-to-right-lobe ratio greater than 0.65 is a well-validated morphological marker for cirrhosis. Gamna-Gandy bodies — siderotic foci within the spleen reflecting hemosiderin deposition at sites of microhemorrhage — are seen in approximately 9–12% of portal hypertension patients and are pathognomonic of advanced portal hypertension [25].

The fundamental limitation of CT for fibrosis staging is that most morphological changes detectable by this modality reflect advanced disease. CT is poorly sensitive for pre-cirrhotic fibrosis. Moreover, the use of ionizing radiation and iodinated contrast agents limits its suitability for repeated monitoring. Emerging

CT-based approaches including texture analysis, radiomics, and portal hypertension-related signature extraction remain research tools at present.

The clinical value of radiological imaging in chronic hepatitis lies not merely in its diagnostic accuracy but in its translation into treatment decisions that interrupt fibrosis progression. In patients with HCV, identification of significant fibrosis (F2) on imaging represents a strong indication for initiating DAA therapy. Achieving sustained virological response (SVR) with DAAs not only halts fibrosis progression but can induce measurable regression in liver stiffness values, as confirmed by longitudinal TE monitoring studies.

In chronic HBV, elevated liver stiffness on TE or MRE indicating advanced fibrosis guides decisions regarding nucleoside/nucleotide analogue therapy initiation. Bera et al. reviewed evidence supporting the role of noninvasive tests in CHB management and concluded that imaging-based elastography, particularly TE and MRE, should be integrated alongside serum markers (APRI, FIB-4) as the standard approach for determining treatment eligibility [38].

A practical surveillance algorithm incorporating these imaging modalities could be structured as follows: initial assessment with B-mode ultrasonography and TE upon diagnosis of chronic viral hepatitis; repeat TE every 6–12 months in patients with significant fibrosis; DW-MRI as a second-line tool in patients with inconclusive TE results; MRE as the most accurate option in patients requiring high-precision staging; and CT reserved for portal hypertension complications and HCC surveillance.

Conclusions: Radiological imaging has transformed the clinical management of chronic viral hepatitis by providing accurate, reproducible, and noninvasive assessment of hepatic fibrosis — the central pathological process driving progression to cirrhosis. The evidence reviewed demonstrates a clear hierarchy of imaging modalities: conventional ultrasonography excels at screening and

monitoring cirrhosis-related complications; transient elastography and shear wave elastography provide clinically validated, accessible first-line fibrosis staging with strong diagnostic performance; MR elastography represents the gold standard among noninvasive tools with AUC values exceeding 0.91 for significant and advanced fibrosis; and DW-MRI contributes an independent, quantitative parameter particularly valuable for cirrhosis exclusion.

Critically, the clinical application of these imaging tools extends beyond diagnosis to direct prevention of cirrhosis. By enabling timely identification of fibrosis stages that require antiviral intervention — before the irreversible architectural destruction of cirrhosis is established — imaging-based surveillance programs offer a concrete mechanism for reducing the global burden of cirrhosis and its life-threatening sequelae.

Future research priorities include: (i) standardization of cutoff values across different elastographic platforms and hepatitis etiologies; (ii) multicenter validation of integrated diagnostic algorithms combining serum markers with imaging modalities; (iii) longitudinal studies quantifying fibrosis regression rates under antiviral therapy as measured by serial imaging; and (iv) investigation of emerging techniques including liver surface nodularity assessment on CT, T1 mapping, and radiomics-based approaches as complementary fibrosis markers.

In conclusion, radiological imaging stands as a cornerstone of modern hepatological care. Its routine and strategic application in patients with chronic viral hepatitis represents one of the most impactful measures available to clinicians for preventing the devastating progression of chronic hepatitis to liver cirrhosis.

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