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Review

Radiological Evaluation of Liver Fibrosis: Elastography, MRI, and Non-Invasive Assessment in Hepatology

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Abstract

Fibrosis represents both a critical milestone and a clinically advanced point on the continuum in chronic liver disease, leading, respectively, to complications of such leading conditions as cirrhosis and hepatocellular carcinoma. The main purpose of this review was to report on efficacy, reliability, and clinical applicability, with an emphasis on the positioning of the above techniques in the practice of hepatology. Methods used to diagnose liver disease include biopsy and radiological evaluation. To date, biopsy has represented a reliable method of diagnosis but is invasive and carries certain risks, which may present some problems related to sampling variability. Such emergency-inducing conditions have now become promising alternatives to liver biopsy that include noninvasive radiological imaging methods like elastography and MRI in their improved safety, consistency, and accuracy for assessing liver fibrosis. Early diagnosis of fibrosis, therefore, supported by accurate diagnostics, will be fundamental for effective clinical management and improved outcomes. This article reviews new developments in the radiological assessment of liver fibrosis and focuses on the following: transient elastography, shear wave elastography, and MRI-based approaches such as magnetic resonance elastography, among other non-invasive approaches. The integration of AI, imaging using new biomarkers, personalizing diagnostic approaches, and improved non-invasive methods will help in better evaluation, more accurate diagnosis, and tailored hepatology treatment.

Keywords: *fibrosis, invasive, radiology, MRI, elastography*

Introduction

Hepatic fibrosis is a pathophysiologic state in which the accumulation of extracellular matrix proteins occurs in the liver. This state occurs as a result of inflammation, chronic liver injury, or habitual damage caused by viral infection, metabolic disorders, or alcohol intake. It encompasses an activated hepatic stellate cell and a sequential stage of inflammation and fibrogenic reactions. Clinically, the stage of liver fibrosis could be progressed to liver cirrhosis, liver failure, until it deteriorates and eventually leads to hepatocellular carcinoma (1).

Hepatic fibrosis assessment becomes important in the study of liver diseases because through this condition, its early diagnosis, prognosis determination, and therapy guidance with a view will improve the clinical outcome of patients. Liver biopsy has been presented as a reliable method of diagnosis, but it also has huge drawbacks, among these drawbacks: risk of infection, bleeding, and surrounding organ damage complications. Further, sampling errors may occur for fibrosis or cirrhosis generally a heterogeneous process, and a small amount of tissue biopsy usually assessed during sampling might not reflect the actual overall state; this may well lead to wrong detection of case severity (2).

The increase in the prevalence of liver fibrosis and cirrhosis calls for the urgency of having non-invasive diagnostic methods, and to avoid the undesirable disadvantages of biopsy methods. Non-invasive tools, such as transient elastography (TE), advanced imaging methods, and biomarkers, address these by providing more economical, and safer repeatable alternatives. These tools have been receiving even greater attention due to the increasing incidence of liver conditions through NAFLD, viral hepatitis, and alcohol-related liver disease. The early detection, follow-up in the course of disease, and therapeutic decisions based on reliable non-invasive diagnostics can help improve the patients' outcome and decrease the healthcare burden. Consequently, their development and validation still constitute an important issue in hepatology (3).

This review focuses on recent advances in radiological evaluation of liver disease for the assessment of liver fibrosis, focusing on non-invasive techniques. Liver fibrosis is a crucial stage during CLDs, where timely diagnosis and staging are important for clinical management and therapeutic follow-up. We underscore three main domains of non-invasive evaluation methods: elastography, magnetic resonance imaging (MRI), and other new emerging methods. Liver elastography has gained a wide following for its ease of providing quantification for liver stiffness as a surrogate for fibrosis. Elastography includes TE, shear wave elastography (SWE), acoustic radiation force impulse (ARFI), and other types of elastography. Equally, other methods use magnetic resonance imaging, like magnetic resonance elastography (MRE), diffusion-weighted imaging (DWI), and other MRI-based methods, providing detailed functional and structural insights into liver cases that are more sensitive and reproducible than ultrasound (4). Furthermore, they consistently provide reliable quantitative and qualitative assessments of liver fibrosis and stiffness with an enhanced safety profile. Besides, we discuss other non-invasive complementary methods comprising AI-integrated imaging models and serum biomarker-based scoring systems that have promised better diagnostic precision. Over the last decades, further and further noninvasive styles have gained popular acceptance in clinical practice (5). This review has compared the diagnostic accuracy, strengths, limitations, and clinical applicability of these techniques to provide ways in which liver fibrosis is optimally evaluated in hepatology practice.

Methodology

This review utilized a comprehensive search of peer-reviewed articles from Scopus, Cochrane, and PubMed databases. A combination of specific keywords, including *liver fibrosis*, *hepatology diagnostic methods*, *elastography*, *non-invasive evaluation*, *MRI*, *biomarkers*, *recent imaging*

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techniques, and *hepatology*, was utilized to retrieve articles published up to 2024. Articles were included if they discussed radiological evaluation techniques such as TE, SWE, ARFI, and MRI-based methods, including MRE and DWI. Additionally, studies that compared different imaging modalities and incorporated novel approaches, such as artificial intelligence (AI), to enhance the non-invasive assessment of hepatic fibrosis were prioritized. The results highlight current challenges and propose advanced directions for future research in the field.

Discussion

Overview of Liver Fibrosis Staging

Liver fibrosis is a progressive process of scar formation due to chronic liver injury in which an accumulation of excessive extracellular matrix protein leads to inflammation, the release of many cells, including cytokines, and activation of hepatic stellate cells. Liver fibrosis progresses through various stages, starting from F0 to F4, and is staged based on the histological finding: stage 0 (F0), in which there is no fibrosis; stage 1 (F1), which refers to mild periportal fibrosis without septa; stage 2 (F2), which is periportal fibrosis and occasional septa; stage 3 (F3), which is bridging fibrosis between vascular tissue in the liver; and stage 4 (F4), which is fibrosis converted to cirrhosis, tissue distortion, and regenerative nodules (6). Knowledge of these stages is helpful in the evaluation of the severity of the disease and treatment intervention. Accurate fibrosis staging is important for evaluation of liver fibrosis, disease management, treatment planning, and surveillance strategy. It will inform if there is need for lifestyle modification, antiviral therapy, or other interventions aimed at preventing disease progression. In addition, it will determine suitability for liver transportation procedures, thus enhancing outcome and resource utilization in patients with chronic hepatic disease (7).

Non-Invasive Assessment of Modalities for Liver Fibrosis

Elastography for liver fibrosis

It is believed that the use of liver elastography is significantly contributing to the non-invasive assessment of liver fibrosis. Besides assessing the stiffness of tissues, it also acts as an indirect marker of fibrosis (8).

Transient Elastography (TE)

TE is very well known under the trade name FibroScan. Through mechanically driven impulse share- wave to get a single measurement. Its repeatability and ease of performance have contributed to its considerable popularity. The results are obtained fast. TE displays very good sensitivity and specificity. Significant cirrhosis and fibrosis can be detected with it. However, some conditions, such as obesity, ascites, and constrained intercostal spaces, limit it (9, 10).

Shear-Wave Elastography (SWE)

SWE is an ultrasound-based elastography method that provides quantitative measurement of stiffness and real-time imaging. Through creating real-time 2D and 3D images by using a specialized ultrasound machine (SuperSonic) to create a MACH cone share-wave pulse (11). Because of its high accuracy and spatial resolution, SWE is well-suited for diagnosing liver diseases of various etiologies. This technique is less dependent on patient factors compared with TE and is independent of the operator (10).

Acoustic Radiation Force Impulse Elastography (ARFI)

It is an advanced imaging fashion in which there is the generation of an aural shear surge over a region of interest with an aural drive-palpitation. Latterly, the exact estimation of pliantness in a particular towel takes place with the response of towel relegation. Measures per second is the unit of dimension for the speed at which shear swells propagate (12).

Still, the magnitude of the peak relegation is equally commensurable to the towel's pliantness, determined by the Young modulus. It has also been illustrated that the stiffness of the towel is commensurable to both the time to peak relegation and recovery time. This technique is less dependent on patient factors compared with TE and is independent of the operator (9).

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Comparison of Elastography Methods

TE represents a broadly used technique that can quickly evaluate liver fibrosis; however, there is no possibility of imaging. Some of the disadvantages are a lack of imaging capability and a decrease in accuracy with obesity or ascites. SWE has greater sensitivity and specificity compared to TE, with the added advantage of real-time imaging and precise liver fibrosis and accurate liver stiffness localization, which is a competitive advantage in the heterogeneous condition of the liver (13). ARFI elastography, while integrated into conventional ultrasound devices, provides depth-specific stiffness measurements, balancing sensitivity and specificity, but may have lower accuracy in advanced fibrosis (14).

Magnetic Resonance Imaging (MRI)

MRI methods are used for the evaluation and diagnosis of liver fibrosis; these techniques have improved the diagnostic yield (9).

Magnetic Resonance Elastography (MRE)

MRE is believed to be the most sensitive non-invasive imaging modality. It produces high-resolution maps of liver stiffness by amalgamating MRI with low-frequency mechanical waves. It has excellent reproducibility and is very accurate in differentiating between the different stages of fibrosis (10, 15).

Diffusion-Weighted Imaging (DWI)

This technique is based on the dislocation of water molecules in the liver and gives a quantitative measure of liver fibrosis. Many studies have demonstrated the clinical value of this technique in detecting early fibrosis and disease course assessment. MRI techniques are more sensitive than ultrasound techniques in the diagnosis, especially of patients with extreme obesity (9).

Comparison of MRE with Other Imaging Modalities

Magnetic resonance Elastography is thought to be better than other imaging methods, including TE, SWE, and ARFI. MRE can be used more frequently in situations of obesity and ascites because of its increased accuracy and dependability. Furthermore, whole-liver evaluation utilizing MRE shows less operator reliance, which improves its diagnostic accuracy in contrast to the other methods mentioned above (16).

Table 1: Elastography and MRI advantages and disadvantages (9, 17, 18)

Imaging modalities	Advantages	Disadvantages
Elastography		
Transient Elastography (TE)	Timesaving, low cost, user-friendly, widely used.	Affected by factors such as food intake and obesity, expensive requirements.
Shear-Wave Elastography (SWE)	High resolution, operation independently, reproducibility, easy and rapid non-invasive technique.	Limited penetration, poor acoustic.
Acoustic Radiation Force Impulse Elastography (ARFI)	More reliable than TE for severe liver fibrosis or cirrhosis, friendly to be used.	Influenced by biological factors such as age, obesity, sex, expensive equipment and requirements
Magnetic Resonance Imaging		
Magnetic Resonance Elastography (MRE)	More accurate for significant fibrosis, high repeatability and applicability, assesses the whole liver	Specialized knowledge requirements, expensive, time-consuming
Diffusion-Weighted Imaging (DWI)	Ideal with sclerosing cholangitis patients	Time-consuming, affected by biologic factors such as inflammation

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Other Non-Invasive Assessment in Hepatology

Non-invasive diagnostic tools play a crucial role in the assessment and management of liver fibrosis, offering accurate and cost-effective strategies that eliminate the need for invasive procedures. Serum biomarkers, such as APRI and FIB-4, when combined with imaging techniques, enhance the evaluation of liver fibrosis. These biomarkers provide non-invasive, accurate, and inexpensive diagnostic options, which are essential for clinical decision-making and management in hepatology practice (16).

Imaging techniques also contribute significantly to the non-invasive assessment of liver fibrosis. CT imaging provides an indirect evaluation by detecting morphologic changes associated with fibrosis. Advanced methods, such as CT-based texture analysis and radiomics, further improve sensitivity and hold promise as potential non-invasive biomarkers. Similarly, ultrasound elastography, when paired with traditional ultrasonography, measures tissue stiffness to diagnose hepatic fibrosis (19, 20). This technology is non-invasive and enhances diagnostic accuracy, making it a valuable tool in clinical practice.

Together, serum biomarkers and imaging modalities represent a comprehensive approach to the non-invasive assessment of liver fibrosis, aiding in better diagnosis and management strategies.

Comparative Effectiveness of Elastography and MRI

Elastography and MRI are two techniques that have vastly improved the assessment of liver fibrosis. Each modality has unique advantages that allow physicians to tailor the diagnostic strategy in specific patient scenarios. Given that it is relatively inexpensive and easy to perform and access, elastography is a particular technique known as TE, which is a very important modality in the assessment of liver fibrosis. It represents a really non-invasive technique that makes use of liver stiffness as a surrogate in assessing fibrosis (21). This is appropriate for routine clinical use, especially in resource-poor settings, where multiple studies have shown its utility in distinguishing early from advanced stages of fibrosis. The portability of elastography equipment further extends their application to outpatient and community health programs (22). By contrast, MRI-based technologies, including MRE and advanced quantitative imaging methods, will be able to diagnose it with higher accuracy and allow more detailed assessment of the liver parenchyma. While MRE is more costly and less widely available than TE, it retains high sensitivity and specificity, especially in those obese, with ascites, or when TE examinations are inconclusive (15). It allows the assessment of the distribution of fibrosis, enabling more accurate staging and detection of concomitant liver pathologies. It is, therefore, regarded as the gold standard in complex cases or research, where detailed imaging is necessary (23).

The integration of these imaging techniques along with serum biomarkers further developed a comprehensive strategy toward the diagnosis of liver fibrosis. Biomarkers like the FIB-4 index and APRI further complement imaging by providing biochemical information related to the liver. This is also in tandem with recent guidelines, which emphasize tailoring the diagnostic pathway to meet the individual needs of the patient in as cost-effective yet clinically efficacious manner as possible (24, 25). Overall, however, the distinct dual facets of the liver fibrosis radiology from the whole characterization are probably MRI and the elastography sensitivity that can be used in a periodic screening and follow-up. Biomarkers can complement these methods, and together they may serve as a powerful, flexible system that can further enable better liver disease management (26).

Integration of Artificial Intelligence (AI) in Imaging Diagnostics

Artificial intelligence and the objectification of machine literacy ways in imaging systems grossly enhance the discovery rate and fast staging of liver fibrosis. Similar advanced technologies allow for recycling a large volume of data, the discovery of nanosecond patterns, and lower driver variability for further standardization of approach in opinion. Also, the design of movable imaging bias can extend non-invasive diagnostics beyond

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primary-care medical installations, especially in regions with low vacuity of imaging modalities, similar to resource-poor countries (27).

Current challenges and limitations

Non-invasive techniques of liver fibrosis face several challenges that can limit their effectiveness. Technological obstacles, such as limited accessibility, high costs, and the non-standardization of diagnostic equipment, can impact the reproducibility and reliability of results. Additionally, patient-dependent factors, including conditions like obesity, ascites, or other comorbidities, may reduce the sensitivity of imaging techniques, making accurate diagnosis more difficult (28). Another significant challenge lies in the interpretation and clinical adoption of these methods. Variability in reporting standards often makes it difficult for clinicians to understand and integrate the results into routine practice. Addressing these limitations is essential to optimize the diagnostic benefits of non-invasive approaches and ensure their effective application in hepatology (29).

Future Directions and Emerging Trends

When combining the strengths of all these imaging modalities, such as elastography and MRI, for fibrosis staging, diagnostic accuracy is considerably improved and provides a comprehensive assessment of both liver stiffness and tissue property (30). The combination of imaging methods with serum biomarkers for cytokeratin-18 or hyaluronic acid demonstrates potential in the improvement of diagnostic accuracy and early, specific intervention in liver fibrosis. Cost-effectiveness will be a requirement for wide adoptions in resource-poor settings. Simplification of procedures could close the gaps, along with creative funding that would make modern diagnostics accessible worldwide and guide public health efforts.

Conclusion

Although elastography is superior in accessibility and cost-effectiveness, MRI has superior precision in the advanced staging of liver fibrosis. The integration of these two non-invasive imaging modalities into clinical practice will contribute toward the early diagnosis and monitoring required, with an added advantage of reducing dependence on invasive biopsy. Further studies should be channelled to leverage AI so that diagnostic performance can be further improved while proposing and building multimodal approaches by which different imaging modalities may offer a more comprehensive assessment of the state of liver fibrosis.

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Conflict of interest

There is no conflict of interest.

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Data availability

Data that support the findings of this study are embedded within the manuscript.

Author contribution

All authors contributed to conceptualizing, data drafting, collection and final writing of the manuscript.

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