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ULTRASOUND VS. MRI IN HEPATOCELLULAR CARCINOMA: THE BATTLE FOR DIAGNOSTIC SUPREMACY

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Hepatocellular carcinoma", "Ultrasound imaging", "MRI in HCC" and "Liver cancer imaging

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Abstract

Background: *Hepatocellular carcinoma (HCC) is the most common primary malignancy of the liver, often arising in the setting of chronic liver disease and cirrhosis. Accurate imaging is critical for diagnosis, staging, treatment planning, and follow-up.*

Objective: *To compare the diagnostic accuracy of Ultrasound and Magnetic Resonance Imaging in the diagnosis of hepatocellular carcinoma.*

Methodology: *Published reports of comparing the diagnostic accuracy of Ultrasound with Magnetic Resonance Imaging in the diagnosis of hepatocellular carcinoma were identified by a systematic search of Google Scholar, PubMed, Research Gate, Springer and the Sci Hub, supplemented with citation tracking. From 950 initially identified studies, only 27 studies met the inclusion criteria after screening and duplicate removal. These studies compared the diagnostic accuracy of Ultrasound and Magnetic Resonance Imaging in the detection and diagnosis of hepatocellular carcinoma, using standard statistical measures, typically at a 95% confidence level.*

Results: *Ultrasound (US) and magnetic resonance imaging (MRI) are two pivotal non-invasive imaging modalities used in the detection and characterization of HCC. US is widely accessible, cost-effective, and commonly used for initial screening, especially in high-risk populations. However, its sensitivity can be limited, particularly for small or isoechoic lesions. MRI, on the other hand, provides superior soft tissue contrast and functional imaging capabilities, allowing for better lesion characterization and detection of smaller tumors. The integration of both modalities, especially when combined with contrast agents and dynamic imaging protocols, can significantly improve diagnostic accuracy and patient management. Ongoing advancements in imaging techniques and artificial intelligence applications are also contributing to early detection and improved outcomes in HCC care.*

Conclusion: *This systematic review demonstrates that USG and MRI are complementary tools in the imaging of hepatocellular carcinoma. While ultrasound remains essential for surveillance, MRI stands out for its superior diagnostic accuracy and lesion characterization capabilities. The integration of both modalities offers an optimized approach for the early detection and*

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management of HCC.

INTRODUCTION

Hepatocellular carcinoma (HCC) constitutes a major global health burden, being the sixth most common cancer and the third leading cause of cancer-related death worldwide (Bray et al., 2018). Early diagnosis is essential for improving prognosis and expanding treatment options. The surveillance of at-risk populations primarily employs imaging modalities to detect tumors at an early, curative stage (Moher et al., 2009). Among the array of imaging techniques, ultrasound (US) and magnetic resonance imaging (MRI) have emerged as frontline tools due to their non-invasiveness and ability to provide detailed structural and functional information about hepatic lesions (Shea et al., 2017). HCC most commonly arises in the context of chronic liver disease and cirrhosis, particularly those related to hepatitis B virus (HBV), hepatitis C virus (HCV), and non-alcoholic steatohepatitis (NASH) (Forner, Reig, & Bruix, 2018). The transformation from inflammation to fibrosis and eventually neoplasia necessitates ongoing surveillance in at-risk populations. This stratification enables early intervention, which is directly correlated with increased survival rates and a broader range of therapeutic options (Yang et al., 2019). Ultrasound (US) is frequently used for HCC surveillance due to its low cost, safety, and accessibility. It is effective in detecting liver nodules larger than 1 cm and is often used in combination with serum alpha-fetoprotein (AFP) measurements (Singal et al., 2020). However, its sensitivity is variable and often reduced in obese patients or those with coarse echotexture due to advanced cirrhosis, potentially leading to missed early-stage tumors (Tzartzeva et al., 2018). Magnetic Resonance Imaging (MRI), especially when enhanced with hepatocyte-specific contrast agents like gadoxetic acid, offers higher sensitivity and specificity compared to US (van der Pol et al., 2019). MRI provides superior soft-tissue contrast and functional imaging that is particularly beneficial in characterizing small hepatic nodules. Nevertheless, its widespread use is limited by cost, time requirements, and limited availability in low-resource settings (Kim et al., 2019). Emerging technologies such as contrast-enhanced ultrasound (CEUS), diffusion-weighted imaging (DWI), and radiomics are paving the way for more precise HCC diagnosis. Radiomics, which extracts high-dimensional data from images, holds promise in developing predictive models for tumor behavior and treatment response (Lubner et al., 2017). Integration of artificial intelligence (AI) and machine learning into imaging analysis may further enhance diagnostic accuracy and facilitate individualized patient care (Shin et al., 2020). Despite technological progress, early detection of HCC remains a challenge. Current guidelines recommend biannual surveillance with ultrasound in at-risk individuals, but adherence and diagnostic performance vary globally (Marrero et al., 2018). A multidisciplinary approach combining clinical, laboratory, imaging, and histopathological data is essential to overcome diagnostic limitations and improve overall patient outcomes in the management of HCC (Lee et al., 2015) Hepatocellular carcinoma (HCC) is the most common primary liver cancer, and imaging plays a vital role in its early detection and diagnosis. Ultrasound (US) is often used as the first-line imaging modality in surveillance programs due to its wide availability and non-invasive nature. However, its sensitivity decreases with smaller lesions and obese patients, necessitating additional imaging tools like MRI for comprehensive evaluation (Singal et al., 2014). Contrast-enhanced ultrasound (CEUS) has significantly improved the diagnostic performance of traditional ultrasound by allowing dynamic vascular imaging. It enables real-time assessment of enhancement patterns in liver lesions, which helps in differentiating HCC from other focal liver lesions (Claudon et al., 2013). The Liver Imaging Reporting and Data System (LI-RADS) for CEUS was developed to bring standardization in interpretation. CEUS LI-RADS helps classify liver nodules based on features like arterial phase hyperenhancement and washout, increasing diagnostic accuracy and interobserver agreement (Ferraioli et al., 2018). Magnetic resonance imaging (MRI), particularly with dynamic contrast enhancement, is considered the most sensitive imaging method for detecting and characterizing HCC. MRI provides superior soft tissue contrast and can accurately evaluate tumor

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size, vascular invasion, and intrahepatic spread (Kim et al., 2016). The use of hepatocyte-specific contrast agents in MRI, such as gadoxetic acid (Gd-EOB-DTPA), has further improved lesion detection. These agents are selectively taken up by hepatocytes, helping distinguish HCC from benign nodules during the hepatobiliary phase (Jang et al., 2012) MRI LI-RADS classification mirrors the CEUS LI-RADS in its effort to standardize reporting. The system incorporates imaging features such as non-rim arterial phase hyperenhancement, washout appearance, and capsule appearance to stratify lesion likelihood (Elsayes et al., 2017). Studies show MRI outperforms ultrasound in terms of sensitivity for small HCCs (<2 cm). While ultrasound sensitivity may be around 60–70%, MRI with hepatobiliary contrast agents can reach up to 90% sensitivity for early lesions (Park et al., 2014). Despite the strengths of MRI, CEUS holds value where MRI is contraindicated or unavailable. It offers real-time imaging without radiation and is particularly useful in patients with renal impairment who cannot receive gadolinium-based contrast agents (Bartolotta et al., 2015) (Tang et al., 2018).

MATERIALS AND METHODS:

STUDY DESIGN:

This study is a systematic review of multiple articles that were published till the month of May, 2025 that compares the diagnostic accuracy of USG with MRI for the detection and diagnosis of HCC. This study is reported in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines as shown in figure 1. No meta-analyses were included in the study.

SEARCH STRATEGY:

Published reports that compared the diagnostic accuracy of USG with MRI for the detection and diagnosis of HCC were identified by a systematic search of Google Scholar, PubMed, ResearchGate, Science direct, Springer and the Sci Hub, supplemented with citation tracking. The search was made using combinations of the following keywords: "Hepatocellular carcinoma", "Ultrasound imaging", "MRI in HCC" and "Liver cancer imaging". In addition, BOOLEAN operators such as "AND" and "OR" were used for efficient search strategy.

INCLUSION AND EXCLUSION CRITERIA:

Publications published till May 2025 were included in our study. From 999 initially identified studies, 27 studies met the inclusion criteria after screening and duplicate removal. The studies included original articles and reviews that consisted of at least one of the following terms: "Hepatocellular carcinoma", "Ultrasound imaging", "MRI in HCC" and "Liver cancer imaging.". The inclusion criteria included full text articles exclusively presented in English language. Inclusion criteria targeted adult human studies that were reported on the diagnostic performance of US and MRI in high-risk patients for HCC, such as those with liver cirrhosis or chronic hepatitis B and hepatitis C infection.

The exclusion criteria consisted of conference abstracts, publications in languages other than English or without English translation and studies that did not mark a clear comparison between the diagnostic efficiency of USG and MRI in the diagnosis and follow-up of Hepatocellular carcinoma. In addition, studies focused on pediatric populations or rare liver tumors were excluded.

RESULTS:

The search strategy generated 999 publications.972 studies were excluded as they did not meet the selection criteria. These studies were related to other imaging modalities, other types of cancers or comparison between the diagnostic accuracy of imaging modalities other than USG and MRI for hepatocellular cancer. A total of 27 studies were included and subjected to the comparative quality assessment of imaging technologies in the detection and diagnosis of HCC. The references to these studies are numbered and added to this paper in the references. 599 studies were published in a language other than English and therefore, were excluded from the study. Ultrasound is widely used as the initial screening tool for HCC due to its cost effectiveness and accessibility. In high-risk patients, the sensitivity of conventional US for detecting HCC is 63%, which increases to 85% with the use of contrast-enhanced ultrasound (CEUS) However, US has limited ability to detect small lesions (<2 cm), especially in cirrhotic livers with coarse echotexture. MRI, especially with hepatocyte-specific contrast agents like gadoxetic acid, demonstrates superior

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sensitivity (up to 90%) and specificity (up to 95%) for detecting HCC, including small and atypical lesions. MRI also provides functional information through diffusion-weighted imaging (DWI) and dynamic contrast enhancement, aiding in lesion characterization. In conclusion, both CEUS and MRI have unique strengths in HCC imaging. CEUS is excellent for real-time vascular imaging, while MRI provides detailed anatomical and functional information. The integration of standardized systems like LI-RADS has improved the diagnostic consistency and guided clinical decision-making in HCC management.

TABLE 1: DIAGNOSTIC ACCURACY OF USG AND MRI:

Imaging Modality	Sensitivity	Specificity	Key Strengths	Limitations
Conventional Ultrasound	63%	Moderate	Cost-effective, accessible	Misses small lesions (<2 cm), limited in cirrhosis
Contrast-Enhanced US (CEUS)	85%	High	Real-time vascular imaging, improves detection	Operator-dependent, limited tissue characterization
MRI (Gadoxetic Acid)	Up to 90%	Up to 95%	Detects small/atypical lesions, functional data (DWI, dynamic contrast)	Costly, longer scan time

DISCUSSION:

Ultrasound serves as an effective first-line screening modality for HCC, particularly in resource-limited settings. The incorporation of CEUS significantly enhances lesion characterization by visualizing vascular patterns, which are crucial in diagnosing HCC. However, its performance is highly operator-dependent and limited by patient habitus and liver parenchymal heterogeneity (Choi et al., 2016). MRI, on the other hand, offers comprehensive liver imaging with excellent soft tissue contrast and multiparametric capabilities. The use of dynamic contrast enhancement and hepatocyte-specific agents improves the detection of early-stage HCC and differentiates it from benign lesions. Additionally, MRI provides crucial information for staging and treatment planning (Marrero et al., 2018). Combining US and MRI in a diagnostic algorithm can enhance overall detection rates and reduce false positives. While MRI is more expensive and less available in some regions, its diagnostic accuracy justifies its use, especially in cases where ultrasound findings are inconclusive (Lubner et al., 2017).

CONLUSION:

This systematic review demonstrates that USG and MRI are complementary tools in the imaging of hepatocellular carcinoma. While ultrasound remains essential for surveillance, MRI stands out for its superior diagnostic accuracy and lesion characterization capabilities. The integration of both modalities offers an optimized approach for the early detection and management of HCC.

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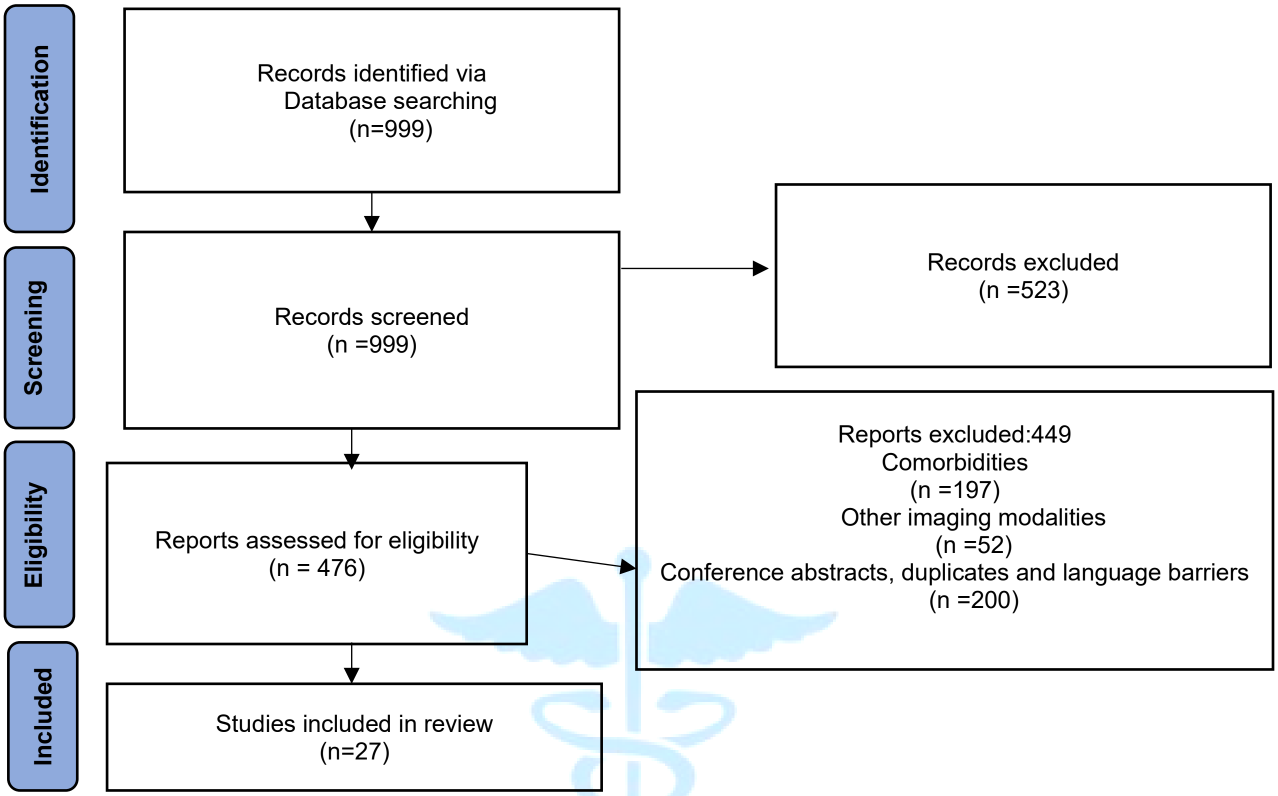
FIGURE 1: PRISMA Flow chart



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