UC San Diego

UC San Diego Previously Published Works

Title

Optimizing Screening of Hepatocellular Carcinoma with Computed Tomography and MR Imaging Emerging Research, Updated Guidelines, and New Technologies

Permalink

https://escholarship.org/uc/item/38h9m3qw

Journal

Radiologic Clinics of North America, 64(3)

ISSN

0033-8389

Authors

An, Julie Y

Dane, Bari R

Marks, Robert M

Publication Date

2026-03-01

DOI

10.1016/j.rcl.2026.01.011

Peer reviewed

eScholarship.org Powered by the California Digital Library
University of California

Optimizing Screening of Hepatocellular Carcinoma with CT and MRI: Emerging Research, Updated Guidelines, and New Technologies

Julie Y. An, MD[1], Bari R. Dane, MD[2], Robert M. Marks, MD[1]
[1] Body Imaging Division, Department of Radiology, University of California San Diego, 200 W Arbor Dr, San Diego, CA 92103
[2]Division of Abdominal Imaging, New York University Langone Health, 660 1st Avenue, 1st Floor New York, NY 10016
julieyajiean@gmail.com, bari.dane@nyulangone.org, rmarks@health.ucsd.edu

Journal: Radiologic Clinics of North America
Due Date: 8/1/25
Word Count: 4020 (limit 4,500 words +/- 500 words)
Tables: 2
Figures: 7
Keyword: HCC, Liver, Cirrhosis, Cancer, Surveillance, Oncology, Photon Counting, Magnetic Resonance Imaging, Photon Counting (limit 8)

Correspondence:
Robert M. Marks, MD
University of California San Diego, Department of Radiology
200 W Arbor Dr, San Diego, CA 92103
rmarks@health.ucsd.edu

Disclosures: Dr. Bari Dane has the following disclosures: 1) speaker honorarium, research and travel support from Siemens Healthineers, 2) Olympus IBD advisory board. Dr. Robert Marks has the following disclosures: 1) consultant and member of speaker bureau for Bayer Healthcare LLC

Abstract/Synopsis:

Ultrasound is the standard first-line imaging modality for HCC screening; however, in certain patient populations, sensitivity is limited and thus alternative strategies are needed in these select patients. This article will provide an overview of MRI and CT for the screening of HCC, with an

emphasis on abbreviated MRI (AMRI) protocols and recent advancements in CT technology (dual energy and photon-counting CT).

Key Points:

- Liver cancer is the 3rd leading cause of cancer related death globally.
- When ultrasound is suboptimal in certain populations for screening for hepatocellular carcinoma, other modalities including MRI or CT should be considered.
- Abbreviated MRI protocols are efficacious and cost-effective alternatives and can be acquired in ~10–15 minutes.
- Newer CT technologies (modern reconstruction algorithms and spectral CT including dual energy and photon counting CT) have the potential to dramatically lower the radiation exposure and improve lesion conspicuity.
- Screening modality and technique decisions should be tailored for each patient, local practice standards and preferences, and availability of resources.

Introduction

Background on Hepatocellular Carcinoma Screening

Hepatocellular carcinoma (HCC) is the most common primary malignant liver tumor and the third leading cause of cancer-related mortality internationally[1,2]. HCC primarily arises in the setting of chronic liver disease. It is associated with hepatitis B in eastern countries and with chronic hepatitis C, alcohol, or metabolic dysfunction-associated fatty liver disease (MAFLD)/metabolic dysfunction-associated steatohepatitis (MASH) in Western countries[3].

In some parts of the world the incidence-to-mortality ratio of liver cancer is close to 1, exemplifying the importance of early cancerous lesion detection[1]. The dismal prognosis of HCC is largely due to delayed diagnosis, with more than two-thirds of patients diagnosed at a stage ineligible for curative treatment or therapy[4]. International radiology and hepatology societies recommend screening patients at highest risk for HCC with ultrasound (US) and serum alpha-fetoprotein (AFP) every 6 months[5-11] .

Regimented early detection of HCC has been referred to in the literature as both “screening” and “surveillance”. Some favor the term surveillance as it implies continuous monitoring, while others prefer the term screening because surveillance is often used in reference to the monitoring of known disease. For consistency and brevity, we will utilize the term screening in this paper.

Current Recommended Screening Strategy

Abdominal US is the primary screening modality due to its wide-spread availability, affordability, and well tolerance, and acceptable diagnostic accuracy. The topic of US screening is covered in a separate chapter and thus will not be discussed in detail in this chapter.

US screening is supported by many studies including a randomized clinical trial performed in China, which found a 37% reduction in mortality in those with chronic Hepatitis B who received a combination of US and AFP screening[12]. Cohort studies have also shown benefits from HCC surveillance and improved clinical outcomes such as early diagnosis, curative treatment and lower mortality in patients with cirrhosis[13].

However, the sensitivity of US in the screening setting is limited in certain patients—specifically those with morbid obesity, severe hepatic steatosis, and/or Child-Pugh C cirrhosis[14]. When liver visualization is impaired by these factors, the sensitivity for detecting early-stage HCC is reduced. In a contemporary study from North America evaluating the adequacy of US for HCC detection, 5.2% of exams were found to have severe limitations (US LI-RADS visualization score C). This same study found exams with severe limitations (visualization score C) had a sensitivity

of 27% compared to nearly 80% for visualization score A and B.[15] Guidelines from LI-RADS US Surveillance suggest transitioning to other imaging modalities such as MRI or CT in patients with Visualization C screening US exams[7].

Magnetic Resonance Imaging (MRI)

Full Liver MRI for HCC Screening

Dynamic multiphase MRI provides the highest diagnostic accuracy for HCC, surpassing multiphase CT, standard US, and contrast-enhanced ultrasound (CEUS)[16]. Despite its superior performance, full multiphase MRI protocols are not currently considered a cost-effective or scalable strategy for routine population-wide screening due to limited accessibility, longer acquisition and interpretation times, and higher overall cost compared to US. Nevertheless, when US is repeatedly inadequate or non-diagnostic, MRI may be preferred since a non-diagnostic or false positive US could incur more overall cost and potential harm[17].

Recent advancements such as deep learning-based reconstruction, parallel imaging, and compressed sensing have helped reduce MRI scan times. While this paper does not explore the technical details of these methods, these tools can enhance imaging efficiency and help mitigate challenges like long scan times, patient discomfort, and claustrophobia—making MRI a more feasible option for HCC screening.

MRI Technical Recommendations for Full Multiphase Liver MRI

The CT/MRI LI-RADS v2018 core document provides technical recommendations for MRI imaging of HCC[18]. These imaging parameters are applicable for the evaluation of known or suspected HCC. Parameters for a full liver MRI are described below (**Figure 1**):

- **1.5T or 3T scanner**
- **Torso phased-array coil**
- **Required sequences:** in-and-opposed phase, T2 weighted (fat suppression is optional), and multiphase T1 weighted pre and post contrast:
    - Extracellular contrast agent and gadobenate dimeglumine: arterial phase (late arterial phase strongly preferred), portal venous phase, and delayed phase Optional 1–3-hour hepatobiliary phase if gadobenate dimeglumine is used
    - Gadoxetate disodium contrast agent: arterial phase (late arterial phase strongly preferred), portal venous phase, transitional phase (2–5 minutes after injection), and hepatobiliary phase

    - The injection rate for both gadobenate dimeglumine and gadoxetate disodium are the same at 1-2 mL/sec
- **Additional suggested sequences**: diffusion-weighted imaging, subtraction imaging (if not able to be easily generated on PACS), and multiplanar acquisition

Abbreviated MRI (AMRI)

To address economic and logistical barriers of full liver MRI, abbreviated MRI (AMRI) protocols with shorter scan times have been developed. A recent metanalysis showed promising pooled sensitivity of 86% and specificity 95% with AMRI in the detection of HCC[19], even for small or early-stage lesions[20]. AMRI protocols can be completed in ~10–15 minutes, which is considerably shorter than a standard liver MRI, and have comparable diagnostic accuracy to full multiphase examinations. Three AMRI techniques have been explored which vary in the included sequences and are designed to evaluate different features of HCC.

These 3 strategies include: dynamic contrast-enhanced (DCE-AMRI), hepatobiliary phase (HBP-AMRI), and noncontrast (NC-AMRI) **Table 2**. A retrospective study by Violi et al compared these three AMRI types in a screening cohort and found that both DCE- and HBP-AMRI performed well, though no independent reference standard was used to validate results[21]. While all three AMRI protocols appear promising, especially in terms of higher sensitivity and inter-reader agreement compared to US, further prospective studies in true screening populations are needed to clarify their relative diagnostic performance, reproducibility, and clinical utility.

Each AMRI protocol is tailored to the specific imaging feature of HCC being evaluated, prioritizing those with the highest diagnostic yield within the constraints of shortened scan time:

- **Pre-contrast and multiphase postcontrast T1 (multiphase only in DCE-AMRI)**: Accesses arterial phase hyperenhancement, washout, and enhancing capsule
- **Hepatobiliary phase T1 (only HBP-AMRI)**: Identifies lesions with reduced hepatobiliary uptake due to decreased OATP transporter expression in hepatocytes
- **In-phase and opposed-phase T1**: Identifies fat or iron content differing from the background liver. Can be acquired alongside pre-contrast T1 on some MRI systems
- **T2-weighted imaging**: Identifies mild to moderate hyperintensity. Marked hyperintensity (e.g., cysts and hemangiomas) or marked hypointensity suggests benignity

- **DWI/ADC:** Accesses diffusion restriction versus T2 shine-through

Dynamic Contrast-Enhanced Abbreviated MRI (DCE-AMRI)

DCE-AMRI captures pre-contrast, arterial, portal venous, and delayed phase images with an extracellular contrast agent before and following IV contrast administration, while eliminating T2 weighted, diffusion weighted, and in-and-opposed phase sequences. The postcontrast images of DCE-AMRI allows for detection of hallmark features of HCC based on lesion vascularity, which are arterial phase hyperenhancement (APHE), washout, and capsular enhancement (**Figure 2**). Inclusion of the full dynamic contrast enhancement sequences also allows for full lesion categorization at the time of screening without need for follow-up diagnostic imaging.

Retrospective studies which simulate DCE-AMRI utilizing extracted sequences from full liver MRI studies have found a similar diagnostic performance of DCE-AMRI compared to the full liver MRI protocol[22,23]. In a recent prospective dual-center study out of Korea with a majority of the patients having hepatitis B cirrhosis, compared to biannual US, annual DCE-AMRI had a higher diagnostic yield for HCC diagnosis with no difference in false referral rate[24]. In a recent case-control study, DCE-AMRI showed higher sensitivity and specificity compared to US in patients with cirrhosis with significantly higher sensitivity than US in patients with Child-Pugh B cirrhosis, but not Child-Pugh A or C cirrhosis[25].

A weakness of DCE-AMRI is this technique has the potential for overcalling benign perfusion alterations and/or vascular shunts due to enhancement characteristics. The absence of additional sequences for down-grading of suspicious lesions may also result in a greater need for follow-up imaging. Additional limitations of this technique include susceptibility to motion and contrast timing issues.

Hepatobiliary Phase Abbreviated MRI (HBP-AMRI)

HBP-AMRI focuses on the hepatobiliary phase appearance after gadoxetate disodium contrast administration, enabling detection of lesions with impaired hepatocyte function. HCC typically appears hypointense on T1 weighted hepatobiliary phase images due to absent or reduced OATP transporter activity, which impairs contrast uptake. As a result, suspicious lesions appear hypointense relative to the normal surrounding liver parenchyma on the delayed hepatobiliary phase sequence. This approach can be useful for identifying early, small (less than 2 cm) HCC not yet demonstrating classic enhancement detectable on DCE-AMRI[26]. HBP-AMRI has the most robust data of all the AMRI protocols as it has been clinically implemented at several academic centers over the last 10 years[27]. Benefits

of this strategy include high diagnostic accuracy and favorable cost-effectiveness in high-risk populations[21,27-30]. Multiple studies have confirmed HBP-AMRI's favorable cost-effectiveness compared to full MRI and US, with one analysis showing a $3000 per quality-adjusted life year gained advantage over US due to its improved diagnostic accuracy[31].

The patient undergoing HBP-AMRI screening receives a hand-injected intravenous contrast agent in the waiting room and undergoes imaging of all included sequences approximately 20 minutes after injection—including hepatobiliary phase T1, T2, with or without DWI (**Figure 3**). DWI is typically included to maximize diagnostic accuracy[32,33] without substantially increasing acquisition time (approximately 2 minutes)[34].

A key advantage of HBP-AMRI is its extended imaging window, as hepatocyte contrast uptake persists beyond 20 minutes. This allows greater flexibility for acquiring diagnostic post-contrast images compared to the narrower timing window required for DCE-AMRI, and the ability to repeat sequences if needed. In 2024, gadoxetate disodium was reclassified by the American College of Radiology (ACR) as a Group II gadolinium-based contrast agent, indicating a lower risk for nephrogenic systemic fibrosis. This reclassification may slightly expand the pool of patients eligible for HBP-AMRI-based screening, particularly in patients previously excluded due to renal impairment.

Limitations for HBP-AMRI include need for repeat diagnostic MRI after lesion identification in order to fully characterize an observation, reduced utility in patients with elevated bilirubin above 3 mg/dL, diminished background hepatic uptake in advanced cirrhosis, false positive findings due to non-functioning hepatocytes, and poor sensitivity for HCC in areas of confluent fibrosis. Moreover, HBP-AMRI is preferred in patients with normal bilirubin, this limits its applicability in patients with poor liver function. Lastly, HBP-AMRI has increased associated costs compared to DCE and NC-AMRI[35]. It is expected, however, that shorter scan time and improved radiologist efficiency in reading the exam may offset this difference.

Noncontrast Abbreviated MRI (NC-AMRI)

NC-AMRI protocol is comprised of in-and-opposed phase T1-weighted images, T2-weighted images, and DWI images (**Figure 4**). Similar to HBP-AMRI, key sequences may be repeated if initial images are degraded by artifact as this technique does not rely on the dynamic post-contrast appearance of lesions. NC-AMRI relies on the DWI sequence to find lesions that have restricted diffusion and includes the T2-weighted sequence to evaluate for lesions that are very bright like cysts and hemangiomas that may cause T2-shine through on the DWI sequence.

Many retrospective studies have evaluated NC-AMRI in HCC enriched populations, non-surveillance populations, with per-patient sensitivities for HCC ranging from 84% - 92%[36-38]. Additionally, two prospective studies prospective studies on NC-AMRI have evaluated the performance in a surveillance population. One prospective study in a surveillance population showed that annual NC-AMRI did not have a statistically significant higher sensitivity for HCC than bi-annual US [39]. The second study showed that NC-AMRI had a sensitivity of 62% in a surveillance population, but a high specificity ranging from 96-100%[21].

NC-AMRI provides the most limited ability to characterize liver lesions due to the inability to evaluate for major imaging findings of HCC as with DCE-AMRI or hypointense lesions in HBP-AMRI, but may be favored because of shorter scan times, no need for intravenous access or contrast administration, and it is the least costly among AMRI protocols. Furthermore, increased public awareness of gadolinium deposition has led to apprehension among some patients regarding need for repeated lifetime MRI contrast use. NC-AMRI imaging may be an alternative for patients when specific contrast agents supply is limited, in patients who have documented severe allergies, and in those who strongly oppose the use of gadolinium based MRI contrast[40].

A limitation of NC-AMRI is its reliance on the DWI sequence which is often compromised by susceptibility artifact in the upper abdomen near the dome, along the liver margin, and especially the left lobe due to adjacent cardiac motion[41,42]. This limitation may increase false negatives if lesions are present in artifact-prone areas. In a recent meta-analysis, NC-AMRI technique was found to have lower but acceptable sensitivity for early-stage HCC compared to HBP-AMRI (79% vs 87%, respectively)[43]. This study did however show higher specificity of NC-AMRI compared to HBP-AMRI, possibly due to lower false positive rates related to impaired hepatocyte function in some benign lesions and many NC-AMRI studies performed in HCC-enriched populations compared to most of the HBP-AMRI studies performed in surveillance or simulated surveillance populations with lower incidences of HCC.

Computed Tomography (CT)

CT for Hepatocellular Carcinoma Screening

CT provides excellent spatial resolution for the detection of small lesions and is an acceptable alternative modality when MRI and US are suboptimal, contraindicated, or inaccessible. CT is especially useful for patients who cannot follow breathing instructions and those with ascites, which would limit MRI image quality due to the dielectric effect. Other patients who may benefit from CT screening are those with non-MRI compliant metal in their bodies, those who have

contraindication for MRI contrast, and those with severe claustrophobia. CT has the additional advantage of being widely available and fast, relative to MRI, which has a slight diagnostic accuracy advantage over CT for HCC diagnosis[44].

Multiphase CT offers higher sensitivity and positive predictive value (68-71%) compared to US for the detection of HCC (60-66%) but carries concerns regarding cost and potential adverse reactions related to IV contrast[45,46]. Additionally, the lifetime accumulation of ionizing radiation poses a theoretical risk of harm, especially if bi-annual screening is maintained. Thus, although CT has been shown to be superior to US for detection of liver cancer, its routine use is not currently recommended.

CT Technical Recommendations

Liver-specific CT protocols may vary slightly between institutions but generally contain 3-4 phases. The CT/MRI LI-RADS v2018 core document provides technical recommendations for CT imaging of HCC[18]. These recommended parameters are applicable for the evaluation of known or suspected HCC and for screening of patients at risk for HCC:

- **Multidetector CT with ≥ 8 detector rows**
- **Required phases**: late arterial phase, portal venous phase, and delayed (3-5 min) phase
- **Additional suggested phases/reformations**: precontrast (noncontrast) phase if patient has had locoregional treatment such as transarterial chemo- or radio-embolization, multiplanar reformations (e.g. coronal and sagittal)

Emerging Technology: Dual Energy CT

Advancements in dual energy CT and virtual noncontrast (VNC) imaging allow for reduced radiation exposure by the elimination of a true noncontrast acquisition while enabling improved assessment of tumor perfusion through low keV virtual monoenergetic and iodine images (**Figure 5**)[47]. When combined with modern iterative reconstruction algorithms, these technologies can further improve image quality while reducing radiation exposure[48].

Dual energy CT may also improve characterization of detected lesions. Low keV virtual monoenergetic images, which increase the conspicuity of iodine, increase lesion conspicuity compared to the background parenchyma even with a 30% reduction in radiation and contrast dose[49]. Furthermore, dual energy CT has demonstrated higher contrast conspicuity of HCC when compared to monoenergetic 65 keV CT as well as MRI, in both arterial (for the assessment of arterial phase hyperenhancement) and portal venous phase images (for the assessment of washout)[50]. Low keV virtual monoenergetic images available with

dual energy and photon counting CTs can also allow for reduced intravenous contrast volume administration while maintaining diagnostic image quality.

Iodine density is a parameter obtainable from dual energy CT which reflects the iodine content within a voxel. Unlike traditional Hounsfield Units which incorporate the intrinsic tissue attenuation and vary with exam related parameters such as acquisition potential and patient body habitus, iodine density more directly reflects the presence of IV contrast. It has been shown to be a surrogate marker of perfusion in a variety of abdominal imaging applications, including HCC [51-53]. The hallmark arterial phase hyperenhancement of HCC, can therefore be more clearly emphasized on dual energy iodine density images.

Despite the promise of dual energy CT technology, it is limited by its availability and the need for specialized expertise to optimize clinical implementation. Additionally, the advantages of dual energy CT may be superseded by photon counting detector CT, which will be described in the subsequent text. Nevertheless, in settings where dual energy CT is available, this technology may offer a theoretical advantage for HCC screening over conventional energy integrating detector CT.

Emerging Technology: Photon Counting CT

Photon counting CT is a new CT technology which directly measures the energy of photons at the detector. By measuring the energy of individual X-ray photons rather than integrating the energy of all photons as with conventional CT, photon counting CT allows for higher spatial resolution, decreased image noise, lower radiation exposure, improved iodine contrast-to-noise ratio, and the ability to perform multi-energy imaging[54]. The significantly lower radiation doses may be critical for the screening population receiving periodic imaging. High-resolution imaging can be especially valuable for small lesion detection, the assessment of subtle changes over time, and assessment of vascular relationship of suspicious lesions for treatment planning and assessment of vascular invasion. There is currently one commercially available photon counting CT system (NAEOTOM Alpha, Siemens Healthineers, Forchheim, Germany), with others currently under development by other vendors[55].

Photon counting CT allows for reduced radiation exposure with similar to improved image quality due to electronic noise removal at the photon counting detector. For example, in an oncologic cohort photon counting CT had a 43% reduction in the CT dose index product and dose length product with the same image quality and noise as second generation dual-source dual energy CT[56]. In obese patients, which particularly benefit from the noise reduction of photon counting CT, a 25% reduction in CT dose index volume has been reported with

similar to improved image quality compared with second generation dual-source dual energy CT[57]. As obese patients are particularly challenging for US HCC screening, this may be an area of opportunity for photon counting CT (**Figure 6**).

Due to the limited time this technology has been clinically available, there is a paucity of literature to date specific for the HCC screening population. While the benefits of photon counting CT for HCC imaging remain theoretical due to limited clinical data, early studies have shown promising results. For example, photon counting CT has been shown to have improved conspicuity and contrast-to-noise ratio of hypovascular liver metastases at portal venous phase photon counting CT compared with conventional energy integrating detector CT[58]. A recent study with an anthropomorphic phantom imaged at photon counting CT and conventional energy integrating detector CT showed greater sensitivity for detection of small liver lesions (subcentimeter), with a mean sensitivity gain of 4.3% and higher reader rated degree of diagnostic confidence[59]. This study also showed photon counting CT demonstrated higher sensitivity than conventional energy integrating CT when scanned under lower dose conditions in sub-centimeter lesions. Another study of patients with pancreatic adenocarcinoma and portal venous phase CT reported substantial inter-reader agreement of four fellowship-trained abdominal radiologists for metastasis identification at photon counting CT (interclass correlation coefficient (ICC) 0.78) versus moderate agreement at conventional energy integrating detector CT (ICC 0.56)[60]. As all of these studies report improved liver lesion conspicuity at 70 keV images (which have a similar appearance to that of a conventional 120 kVp energy integrating detector CT), the improved iodine contrast-to-noise ratio of photon counting CT is the likely explanation. These studies highlight the potential for future research and clinical applications in adults at risk for HCC.

The improved contrast-to-noise ratio of photon counting CT allows for the ability to reduce intravenous contrast volume. Comparable image quality and detection rates were reported between low intravenous contrast dose portal venous phase photon counting CT 70 keV images and portal venous phase conventional energy integrating detector CT with typical weight-based dosing for the detection of metastatic liver lesions[61]. Another retrospective study in 49 pediatric patients showed that photon counting CT provided superior subjective image quality—despite using 17% lower radiation doses and reduced IV contrast volumes (1 mL/kg vs. 2 mL/kg)[62]. While these studies did not focus on the HCC screening population, their findings suggest promising implications for future applications. As more photon counting CTs become available, future prospective studies may be performed to fully evaluate the clinical utility of photon counting CT for HCC screening. With the dose reduction of CT in modern and novel CT

technologies, CT may become a more suitable screening modality in certain patients.

Patient Specific Approach to HCC Screening

Today, there is much greater access to advanced imaging technologies such as AMRI (abbreviated screening protocols) and spectral CT (dual energy and photon counting CT). The availability of these tools can allow for targeted, patient-specific screening regimens for those who are not ideal US candidates. Given promising early data of these new screening strategies, HCC screening is likely to shift toward a more precision-based approach, with reduced reliance on US for many high-risk patients worldwide.

At many institutions, HCC screening follows a tiered approach based on prior US imaging quality, resource availability, and patient factors (**Figure 7**). First-line screening includes US combined with AFP. If the US is categorized as LI-RADS visualization score C, indicating poor liver visualization, repeat US within three months or alternative imaging should be considered[7]. This is important because the sensitivity of US in visualization C exams is low. A repeat US exam is suggested prior to switching to alternative imaging because patients have a greater than 50% chance of improving their US visualization score on a follow-up exam. However, if a patient has 2 or more visualization C exams, they are more likely to stay visualization C and subsequently would be better served by alternative screening methods.

Alternative imaging selection depends on availability and clinical context. CT is used if MRI is unavailable or contraindicated. For MRI, abbreviated MRI protocols are tailored to the patient. Hepatobiliary phase AMRI is preferred if bilirubin is below 3 mg/dL and gadoxetate disodium is available. If gadoxetate disodium is unavailable or bilirubin is above threshold, dynamic contrast-enhanced MRI is recommended. Noncontrast AMRI is an alternative for patients who cannot receive or refuse MRI contrast.

Although NC-AMRI and HBP-AMRI techniques are more amenable to repeat imaging, patient selection remains important as image quality can still be compromised by motion artifact and breath-holding difficulties. Additionally, the use of gadolinium-based contrast agents introduces risks in patients with chronic kidney disease. MRI may be contraindicated in those with claustrophobia or non-MRI-compatible implants. The need for IV contrast in most protocols, the technical complexities of the examination, and patient selection requirements present additional hurdles. Additionally, MRI costs and availability remaining barriers to full adoption.

Lastly, and perhaps most importantly, a collaborative, patient-centered decision-making process should be employed when selecting an individual's screening strategy. Radiologists play a key role in contributing their specialized expertise to the multidisciplinary team, identifying patients with suboptimal (Visualization C) ultrasound and recommending appropriate alternative screening strategies. In a recent study evaluating patient preferences, patients prioritized early detection of HCC over inconvenience and cost after they were provided detailed information regarding various strategies[63]. Surveyed patients preferred abbreviated MRI (29.0%), followed by full liver MRI (23.3%), novel blood-based biomarkers (20.9%), US (3.4%), and US with AFP for their HCC screening (8.8%)[63]. In a separate study, patients selected higher screening sensitivity and lower cost as the most important factors for which their screening preferences are based[64]. Exam experience related attributes such as the need for IV placement or contrast utilization were less important[64].

Conclusion

Ultrasound remains the standard first-line imaging modality for HCC screening; however, its limited sensitivity in select populations underscores the need for alternative strategies. Abbreviated MRI (AMRI) may be a more accurate and cost-effective alternative in certain high-risk patients. CT may be appropriate for patients in whom US is technically inadequate and MRI is unavailable or contraindicated. Advancements in CT dose-reduction techniques, including iterative reconstruction and spectral CT technology (ie dual energy and photon counting CT), may help mitigate radiation-related risks. Ultimately, the optimal HCC screening strategy should be tailored to each patient, balancing diagnostic performance, clinical applicability, resource availability, and individual preferences.

Tables

Table 1. Target at-risk patient population for hepatocellular carcinoma surveillance based on recommendations from the American Association for the Study of Liver Diseases.

Table 2. A comparison of the various MRI strategies, including full liver MRI protocol as well as the 3 AMRI protocols.

Figures

Figure 1. Imaging protocol of full liver MRI with extracellular contrast agent.

Figure 2. Imaging protocol of dynamic contrast-enhanced abbreviated MRI (DCE-AMRI).

Figure 3. Imaging protocol of hepatobiliary phase abbreviated MRI (HBP-AMRI).
Figure 4. Imaging protocol of noncontrast abbreviated MRI (NC-AMRI).
Figure 5. Example of photon counting CT and dual energy CT, with virtual noncontrast images of both CT techniques.
Figure 6. Dose report of the same patient who received two separate triple phase CTs within one month of each other. The photon counting CT yielded total dose-length product (DLP) of 962 mGy*cm, while the conventional energy integrating CT yielded a total DLP of 1,997 mGy*cm.
Figure 7. Precision-based approach for HCC screening strategy selection, based on our institution's practice.

References

1. Bray F, Laversanne M, Sung H, et al. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA Cancer J Clin*. May-Jun 2024;74(3):229-263. doi:10.3322/caac.21834
2. Besa C, Lewis S, Pandharipande PV, et al. Hepatocellular carcinoma detection: diagnostic performance of a simulated abbreviated MRI protocol combining diffusion-weighted and T1-weighted imaging at the delayed phase post gadoxetic acid. *Abdom Radiol (NY)*. Jan 2017;42(1):179-190. doi:10.1007/s00261-016-0841-5
3. Hwang SY, Danpanichkul P, Agopian V, et al. Hepatocellular carcinoma: updates on epidemiology, surveillance, diagnosis and treatment. *Clin Mol Hepatol*. Feb 2025;31(Suppl):S228-S254. doi:10.3350/cmh.2024.0824
4. Stravitz RT, Heuman DM, Chand N, et al. Surveillance for hepatocellular carcinoma in patients with cirrhosis improves outcome. *Am J Med*. Feb 2008;121(2):119-26. doi:10.1016/j.amjmed.2007.09.020
5. European Association for the Study of the L. EASL Clinical Practice Guidelines on the management of hepatocellular carcinoma. *J Hepatol*. Feb 2025;82(2):315-374. doi:10.1016/j.jhep.2024.08.028
6. Singal AG, Llovet JM, Yarchoan M, et al. AASLD Practice Guidance on prevention, diagnosis, and treatment of hepatocellular carcinoma. *Hepatology*. Dec 1 2023;78(6):1922-1965. doi:10.1097/HEP.0000000000000466
7. American College of Radiology. Ultrasound LI-RADS® v2024 Manual. ACR. https://www.acr.org/Clinical-Resources/Reporting-and-Data-Systems/LI-RADS/Ultrasound-LI-RADS-v2024

8. Cannella R, Zins M, Brancatelli G. ESR Essentials: diagnosis of hepatocellular carcinoma-practice recommendations by ESGAR. *Eur Radiol*. Apr 2024;34(4):2127-2139. doi:10.1007/s00330-024-10606-w
9. Expert Panel on Gastrointestinal I, Bashir MR, Horowitz JM, et al. ACR Appropriateness Criteria(R) Chronic Liver Disease. *J Am Coll Radiol*. May 2020;17(5S):S70-S80. doi:10.1016/j.jacr.2020.01.023
10. Korean Liver Cancer A, National Cancer Center K. 2022 KLCA-NCC Korea practice guidelines for the management of hepatocellular carcinoma. *Clin Mol Hepatol*. Oct 2022;28(4):583-705. doi:10.3350/cmh.2022.0294
11. Omata M, Lesmana LA, Tateishi R, et al. Asian Pacific Association for the Study of the Liver consensus recommendations on hepatocellular carcinoma. *Hepatol Int*. Mar 18 2010;4(2):439-74. doi:10.1007/s12072-010-9165-7
12. Zhang BH, Yang BH, Tang ZY. Randomized controlled trial of screening for hepatocellular carcinoma. *J Cancer Res Clin Oncol*. Jul 2004;130(7):417-22. doi:10.1007/s00432-004-0552-0
13. Singal AG, Zhang E, Narasimman M, et al. HCC surveillance improves early detection, curative treatment receipt, and survival in patients with cirrhosis: A meta-analysis. *J Hepatol*. Jul 2022;77(1):128-139. doi:10.1016/j.jhep.2022.01.023
14. Simmons O, Fetzer DT, Yokoo T, et al. Predictors of adequate ultrasound quality for hepatocellular carcinoma surveillance in patients with cirrhosis. *Aliment Pharmacol Ther*. Jan 2017;45(1):169-177. doi:10.1111/apt.13841
15. Chong N, Schoenberger H, Yekkaluri S, et al. Association between ultrasound quality and test performance for HCC surveillance in patients with cirrhosis: a retrospective cohort study. *Aliment Pharmacol Ther*. Mar 2022;55(6):683-690. doi:10.1111/apt.16779
16. Roberts LR, Sirlin CB, Zaiem F, et al. Imaging for the diagnosis of hepatocellular carcinoma: A systematic review and meta-analysis. *Hepatology*. Jan 2018;67(1):401-421. doi:10.1002/hep.29487
17. Konerman MA, Verma A, Zhao B, Singal AG, Lok AS, Parikh ND. Frequency and Outcomes of Abnormal Imaging in Patients With Cirrhosis Enrolled in a Hepatocellular Carcinoma Surveillance Program. *Liver Transpl*. Mar 2019;25(3):369-379. doi:10.1002/lt.25398
18. American College of Radiology. CT/MRI LI-RADS v2018. ACR. https://edge.sitecorecloud.io/americancoldf5f-acrorgf92a-productioncb02-3650/media/ACR/Files/RADS/LI-RADS/LI-RADS-CT-MRI-2018-Core.pdf
19. Gupta P, Soundararajan R, Patel A, Kumar MP, Sharma V, Kalra N. Abbreviated MRI for hepatocellular carcinoma screening: A systematic review and meta-analysis. *J Hepatol*. Jul 2021;75(1):108-119. doi:10.1016/j.jhep.2021.01.041

20. An JY, Pena MA, Cunha GM, et al. Abbreviated MRI for Hepatocellular Carcinoma Screening and Surveillance. *Radiographics*. Nov-Dec 2020;40(7):1916-1931. doi:10.1148/rg.2020200104
21. Vietti Violi N, Lewis S, Liao J, et al. Gadoxetate-enhanced abbreviated MRI is highly accurate for hepatocellular carcinoma screening. *Eur Radiol*. Nov 2020;30(11):6003-6013. doi:10.1007/s00330-020-07014-1
22. Khatri G, Pedrosa I, Ananthakrishnan L, et al. Abbreviated-protocol screening MRI vs. complete-protocol diagnostic MRI for detection of hepatocellular carcinoma in patients with cirrhosis: An equivalence study using LI-RADS v2018. *J Magn Reson Imaging*. Feb 2020;51(2):415-425. doi:10.1002/jmri.26835
23. Lee JY, Huo EJ, Weinstein S, et al. Evaluation of an abbreviated screening MRI protocol for patients at risk for hepatocellular carcinoma. *Abdom Radiol (NY)*. Jul 2018;43(7):1627-1633. doi:10.1007/s00261-017-1339-5
24. Yoon JH, Choi J-I, Yoo J, et al. Comparison of Annual Dynamic Abbreviated MRI and Biannual Ultrasound for HCC Surveillance in a High-Risk Group: Two-Center Cohort Study. *Liver Cancer*. 2025;doi:10.1159/000548516
25. Seif El Dahan K, Yokoo T, Daher D, et al. Multicenter evaluation of abbreviated MRI and ultrasound for detecting early-stage hepatocellular carcinoma. *JHEP Rep*. May 2025;7(5):101357. doi:10.1016/j.jhepr.2025.101357
26. Sano K, Ichikawa T, Motosugi U, et al. Imaging study of early hepatocellular carcinoma: usefulness of gadoxetic acid-enhanced MR imaging. *Radiology*. Dec 2011;261(3):834-44. doi:10.1148/radiol.11101840
27. Marks RM, Ryan A, Heba ER, et al. Diagnostic per-patient accuracy of an abbreviated hepatobiliary phase gadoxetic acid-enhanced MRI for hepatocellular carcinoma surveillance. *AJR Am J Roentgenol*. Mar 2015;204(3):527-35. doi:10.2214/AJR.14.12986
28. Brunsing RL, Chen DH, Schlein A, et al. Gadoxetate-enhanced Abbreviated MRI for Hepatocellular Carcinoma Surveillance: Preliminary Experience. *Radiol Imaging Cancer*. Nov 2019;1(2):e190010. doi:10.1148/rycan.2019190010
29. Tillman BG, Gorman JD, Hru JM, et al. Diagnostic per-lesion performance of a simulated gadoxetate disodium-enhanced abbreviated MRI protocol for hepatocellular carcinoma screening. *Clin Radiol*. May 2018;73(5):485-493. doi:10.1016/j.crad.2017.11.013
30. Mulgaonkar A, Huang DQ, Siddiqi H, et al. Cost-Effectiveness Analysis of Hepatocellular Carcinoma Surveillance in Nonalcoholic Fatty Liver Disease Cirrhosis Using US Visualization Score C-Triggered Abbreviated MRI. *Am J Gastroenterol*. Jul 01 2024;119(7):1326-1336. doi:10.14309/ajg.0000000000002636

31. Goossens N, Singal AG, King LY, et al. Cost-Effectiveness of Risk Score-Stratified Hepatocellular Carcinoma Screening in Patients with Cirrhosis. *Clin Transl Gastroenterol*. Jun 22 2017;8(6):e101. doi:10.1038/ctg.2017.26
32. Park HJ, Seo N, Kim SY. Current Landscape and Future Perspectives of Abbreviated MRI for Hepatocellular Carcinoma Surveillance. *Korean J Radiol*. Jun 2022;23(6):598-614. doi:10.3348/kjr.2021.0896
33. Wang C, Zhu SC, Liang JH. Value of Abbreviated Magnetic Resonance Sequence in Hepatocellular Carcinoma Screening: A Systematic Review and Meta-analysis. *Acad Radiol*. Jun 2025;32(6):3304-3314. doi:10.1016/j.acra.2024.12.024
34. Jalli R, Jafari SH, Sefidbakht S, Kazemi K. Comparison of the Accuracy of DWI and Ultrasonography in Screening Hepatocellular Carcinoma in Patients With Chronic Liver Disease. *Iran J Radiol*. Jan 2015;12(1):e12708. doi:10.5812/iranjradiol.12708
35. Drugs.com. Comparing Eovist vs Gadavist. https://www.drugs.com/compare/eovist-vs-gadavist? Accessed December 23, 2025
36. Kim YK, Park HJ, Park MJ, Lee WJ, Choi D. Noncontrast MRI with diffusion-weighted imaging as the sole imaging modality for detecting liver malignancy in patients with high risk for hepatocellular carcinoma. *Magn Reson Imaging*. Jul 2014;32(6):610-8. doi:10.1016/j.mri.2013.12.021
37. Chan MV, McDonald SJ, Ong YY, et al. HCC screening: assessment of an abbreviated non-contrast MRI protocol. *Eur Radiol Exp*. Dec 18 2019;3(1):49. doi:10.1186/s41747-019-0126-1
38. Park SH, Kim B, Kim SY, et al. Abbreviated MRI with optional multiphasic CT as an alternative to full-sequence MRI: LI-RADS validation in a HCC-screening cohort. *Eur Radiol*. Apr 2020;30(4):2302-2311. doi:10.1007/s00330-019-06546-5
39. Kim DH, Yoon JH, Choi MH, et al. Comparison of non-contrast abbreviated MRI and ultrasound as surveillance modalities for HCC. *J Hepatol*. Sep 2024;81(3):461-470. doi:10.1016/j.jhep.2024.03.048
40. Marks RM, Ash RM, Lee JT. Gadolinium Deposition and Liver MRI. *Clin Liver Dis (Hoboken)*. Mar 2021;17(3):129-132. doi:10.1002/cld.1024
41. Lewis S, Dyvorne H, Cui Y, Taouli B. Diffusion-weighted imaging of the liver: techniques and applications. *Magn Reson Imaging Clin N Am*. Aug 2014;22(3):373-95. doi:10.1016/j.mric.2014.04.009
42. Son JS, Park HS, Park S, et al. Motion-Corrected versus Conventional Diffusion-Weighted Magnetic Resonance Imaging of the Liver Using Non-Rigid Registration. *Diagnostics (Basel)*. Mar 7 2023;13(6)doi:10.3390/diagnostics13061008
43. Kim DH, Choi SH, Shim JH, et al. Meta-Analysis of the Accuracy of Abbreviated Magnetic Resonance Imaging for Hepatocellular Carcinoma Surveillance: Non-Contrast versus Hepatobiliary Phase-Abbreviated Magnetic

Resonance Imaging. *Cancers (Basel)*. Jun 14 2021;13(12)doi:10.3390/cancers13122975
44. Kim YY, Lee S, Shin J, et al. Diagnostic performance of CT versus MRI Liver Imaging Reporting and Data System category 5 for hepatocellular carcinoma: a systematic review and meta-analysis of comparative studies. *Eur Radiol*. Oct 2022;32(10):6723-6729. doi:10.1007/s00330-022-08985-z
45. Colli A, Fraquelli M, Casazza G, et al. Accuracy of ultrasonography, spiral CT, magnetic resonance, and alpha-fetoprotein in diagnosing hepatocellular carcinoma: a systematic review. *Am J Gastroenterol*. Mar 2006;101(3):513-23. doi:10.1111/j.1572-0241.2006.00467.x
46. Pocha C, Dieperink E, McMaken KA, Knott A, Thuras P, Ho SB. Surveillance for hepatocellular cancer with ultrasonography vs. computed tomography -- a randomised study. *Aliment Pharmacol Ther*. Aug 2013;38(3):303-12. doi:10.1111/apt.12370
47. Ichikawa S, Sofue K, Nakamura Y, et al. Single-Energy, Dual-Energy, and Photon-Counting Computed Tomography of the Liver: Current Development and Clinical Utility for the Assessment of Focal Liver Lesions. *Invest Radiol*. Apr 10 2025;doi:10.1097/RLI.0000000000001187
48. Li M, Fan Y, You H, et al. Dual-Energy CT Deep Learning Radiomics to Predict Macrotrabecular-Massive Hepatocellular Carcinoma. *Radiology*. Aug 2023;308(2):e230255. doi:10.1148/radiol.230255
49. Yoon JH, Chang W, Lee ES, Lee SM, Lee JM. Double Low-Dose Dual-Energy Liver CT in Patients at High-Risk of HCC: A Prospective, Randomized, Single-Center Study. *Invest Radiol*. Jun 2020;55(6):340-348. doi:10.1097/RLI.0000000000000643
50. Pfeiffer D, Parakh A, Patino M, Kambadakone A, Rummeny EJ, Sahani DV. Iodine material density images in dual-energy CT: quantification of contrast uptake and washout in HCC. *Abdom Radiol (NY)*. Dec 2018;43(12):3317-3323. doi:10.1007/s00261-018-1636-7
51. Laroia ST, Bhadoria AS, Venigalla Y, et al. Role of dual energy spectral computed tomography in characterization of hepatocellular carcinoma: Initial experience from a tertiary liver care institute. *Eur J Radiol Open*. 2016;3:162-71. doi:10.1016/j.ejro.2016.05.007
52. Yue X, Jiang Q, Hu X, et al. Quantitative dual-energy CT for evaluating hepatocellular carcinoma after transarterial chemoembolization. *Sci Rep*. May 27 2021;11(1):11127. doi:10.1038/s41598-021-90508-9
53. Li J, Zhao S, Ling Z, et al. Dual-Energy Computed Tomography Imaging in Early-Stage Hepatocellular Carcinoma: A Preliminary Study. *Contrast Media Mol Imaging*. 2022;2022:2146343. doi:10.1155/2022/2146343

54. Dane B, Froemming A, Schwartz FR, Toshav A, Ramirez-Giraldo JC, Ananthakrishnan L. Photon counting CT clinical adoption, integration, and workflow. *Abdom Radiol (NY)*. Dec 2024;49(12):4600-4609. doi:10.1007/s00261-024-04503-5
55. Schwartz FR, Sodickson AD, Pickhardt PJ, Sahani DV, Lev MH, Gupta R. Photon-Counting CT: Technology, Current and Potential Future Clinical Applications, and Overview of Approved Systems and Those in Various Stages of Research and Development. *Radiology*. Mar 2025;314(3):e240662. doi:10.1148/radiol.240662
56. Wrazidlo R, Walder L, Estler A, et al. Radiation Dose Reduction in Contrast-Enhanced Abdominal CT: Comparison of Photon-Counting Detector CT with 2nd Generation Dual-Source Dual-Energy CT in an oncologic cohort. *Acad Radiol*. May 2023;30(5):855-862. doi:10.1016/j.acra.2022.05.021
57. Hagen F, Hofmann J, Wrazidlo R, et al. Image quality and dose exposure of contrast-enhanced abdominal CT on a 1st generation clinical dual-source photon-counting detector CT in obese patients vs. a 2nd generation dual-source dual energy integrating detector CT. *Eur J Radiol*. Jun 2022;151:110325. doi:10.1016/j.ejrad.2022.110325
58. Bette S, Decker JA, Braun FM, et al. Optimal Conspicuity of Liver Metastases in Virtual Monochromatic Imaging Reconstructions on a Novel Photon-Counting Detector CT-Effect of keV Settings and BMI. *Diagnostics (Basel)*. May 14 2022;12(5)doi:10.3390/diagnostics12051231
59. Wildman-Tobriner B, Felice N, Kalisz KR, et al. Photon-Counting CT Effects on Sensitivity for Liver Lesion Detection: A Reader Study Using Virtual Imaging. *Radiology*. Jan 2025;314(1):e241568. doi:10.1148/radiol.241568
60. Kim J, Mabud T, Huang C, et al. Inter-reader agreement of pancreatic adenocarcinoma resectability assessment with photon counting versus energy integrating detector CT. *Abdom Radiol (NY)*. Sep 2024;49(9):3149-3157. doi:10.1007/s00261-024-04298-5
61. Dane B, Mabud T, Melamud K, et al. Reduced Intravenous Contrast Dose Portal Venous Phase Photon-Counting Computed Tomography Compared With Conventional Energy-Integrating Detector Portal Venous Phase Computed Tomography. *J Comput Assist Tomogr*. Sep-Oct 01 2024;48(5):675-682. doi:10.1097/RCT.0000000000001617
62. Schwartz FR, Bache S, Lee R, et al. Photon-counting CT yields superior abdominopelvic image quality at lower radiation and iodinated contrast doses. *Pediatr Radiol*. May 2025;55(6):1202-1211. doi:10.1007/s00247-025-06209-2

63. Woolen SA, Singal AG, Davenport MS, et al. Patient Preferences for Hepatocellular Carcinoma Surveillance Parameters. *Clin Gastroenterol Hepatol*. Jan 2022;20(1):204-215 e6. doi:10.1016/j.cgh.2021.02.024
64. Fazeli S, Covarrubias Y, Bassirian S, et al. Eliciting Patient Preferences for Hepatocellular Carcinoma Screening: A Choice-Based Conjoint Analysis. *J Am Coll Radiol*. Apr 2022;19(4):502-512. doi:10.1016/j.jacr.2022.01.015