Chapter 12

LI-RADS® Technique

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Table of Contents

Abbreviations

AP	Arterial phase
DP	Delayed phase
DWI	Diffusion-weighted imaging
ECA	Extracellular agent
Gd	Gadolinium
HBA	Hepatobiliary agent
HBP	Hepatobiliary phase
IP	In-phase imaging
IV	Intravenous
MPR	Multiplanar reformations
OPTN	Organ Procurement and Transplantation Network
OP	Out-of-phase imaging
PVP	Portal venous phase
T1WI	T1-weighted imaging
T2WI	T2-weighted imaging
TP	Transitional Phase
3D	Three-Dimensional

LI-RADS® Technique

Modalities

Both CT and MRI may be used for assigning LI-RADS diagnostic categories and/or treatment response categories.

- Both modalities have advantages and disadvantages, and both permit noninvasive diagnosis of HCC with high specificity if stringent criteria are applied (i.e., LR-5 criteria).
- LI-RADS does not recommend one modality over another, recognizing that the optimal modality in a particular patient depends on multiple factors, including institutional or practice preference, and may require individualized decisions tailored to the patient and the clinical context.

Note that CEUS can be used to assign diagnostic categories but not treatment response categories. CEUS technique is discussed further in the CEUS Manual. It is not discussed further in this chapter.

Contrast agents and their administration

The use of intravenous (IV) contrast agents is required for assigning LI-RADS diagnostic and/or treatment response categories. LI-RADS categories cannot be assigned on noncontrast CT or noncontrast MRI.

- LI-RADS recommends administration of IV contrast agents using a power injector.
- In general, a weight-based dose should be used. The optimal rate of injection depends on the modality: See *page 12-17* for CT and *page 12-17* for MRI.
- The bolus should be followed immediately by a saline chaser (30-40 mL) at the same injection rate to push residual contrast material out of the IV tubing and from the peripheral veins.

Contrast agents for CT

All contrast agents used for LI-RADS categorization with CT are iodine-based low-molecular-weight (LMW) extracellular contrast agents (ECAs).

Contrast agents for MRI

Two different types of Gd-based contrast agents may be used for LI-RADS categorization with MRI: extracellular contrast agents (ECAs) and hepatobiliary contrast agents (HBAs).

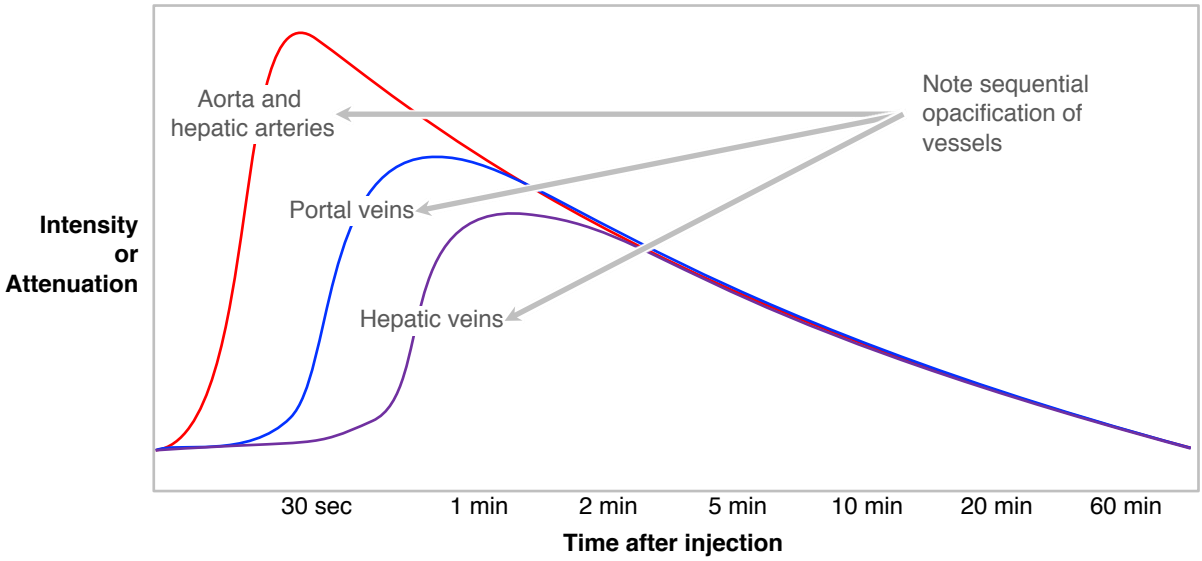
- Both types have advantages and disadvantages. Both permit noninvasive diagnosis of HCC with high specificity if stringent criteria are applied (i.e., LR-5 criteria).
- LI-RADS does not recommend one type of agent over another, recognizing that the optimal agent in a particular patient depends on multiple factors, including institutional or practice preference, and may require individualized decisions tailored to the patient and the clinical context.

Overview

Multiphase imaging

Multiphase image acquisition at sequential time ranges (“dynamic phases”) after contrast administration is required for assigning LI-RADS diagnostic and/or treatment response categories. LI-RADS categories generally cannot be assigned on single-phase CT or MRI.

The dual vascular supply of liver (75% portal venous and 25% hepatic arterial) results in sequential opacification of hepatic arteries, portal veins, and hepatic veins after injection of intravenous contrast, as illustrated in idealized time-intensity curves below.



Different tissues and structures reach peak enhancement at different times. This allows the acquisition of images during different time ranges or “dynamic phases” to highlight these differences.

While these phases are a continuum, they are described as distinct time ranges for simplicity and clinical utility. See page 12-8. As described later, LI-RADS requires certain phases and suggests others.

The phases are selected to:

- Achieve adequate lesion to background contrast **AND**
- Permit characterization of major features; some LR-M features; LR-TIV, ancillary imaging features; and treatment response features.

The exact phases selected depend on the

Modality: CT (page 12-19); MRI (page 12-21) and the type of contrast agent: ECA (page 12-21), Gadobenate dimeglumine (page 12-21), Gadoxetate disodium (page 12-21).

Overview – Extracellular Agents

Extracellular agents distribute in the extracellular space.

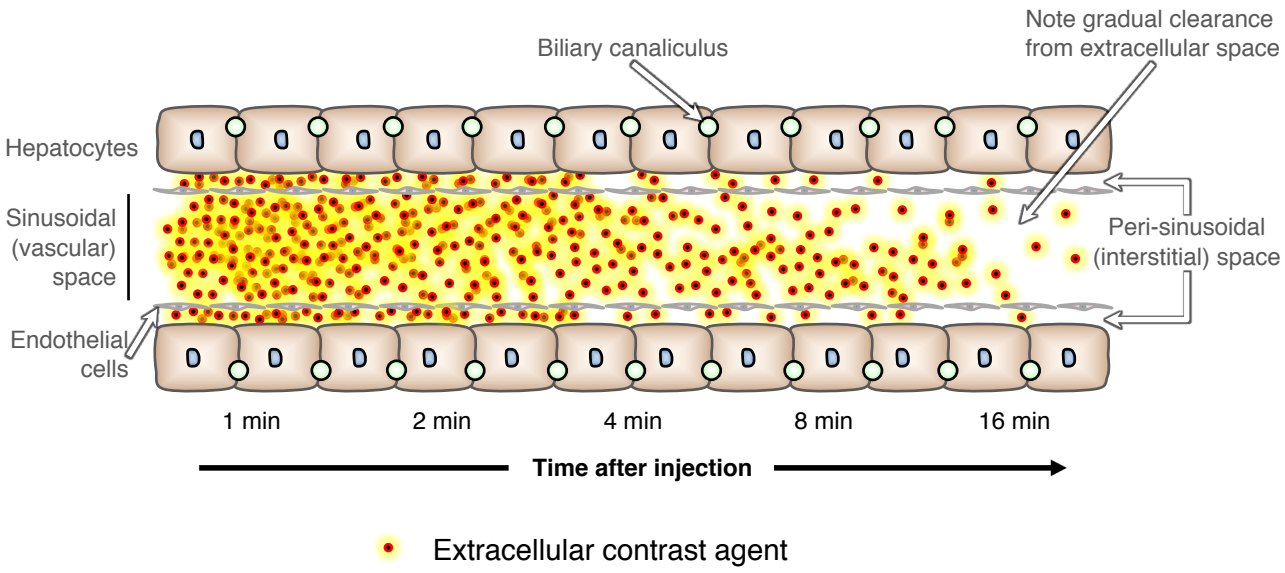
The extracellular space has two components:

- The vascular space
- The interstitial space

In the liver, the vascular space is composed primarily of sinusoids, while the interstitial space is composed mainly of the perisinusoidal space (space of Disse).

Extracellular agents are cleared slowly from the extracellular space since there is only one elimination pathway: excretion by the kidneys via glomerular filtration.

The distribution of ECAs in the extracellular space is illustrated below:



Extracellular agents do NOT distribute in the intracellular or biliary spaces.

Note absence of contrast agent in hepatocytes and biliary canaliculi at all time points in diagram above.

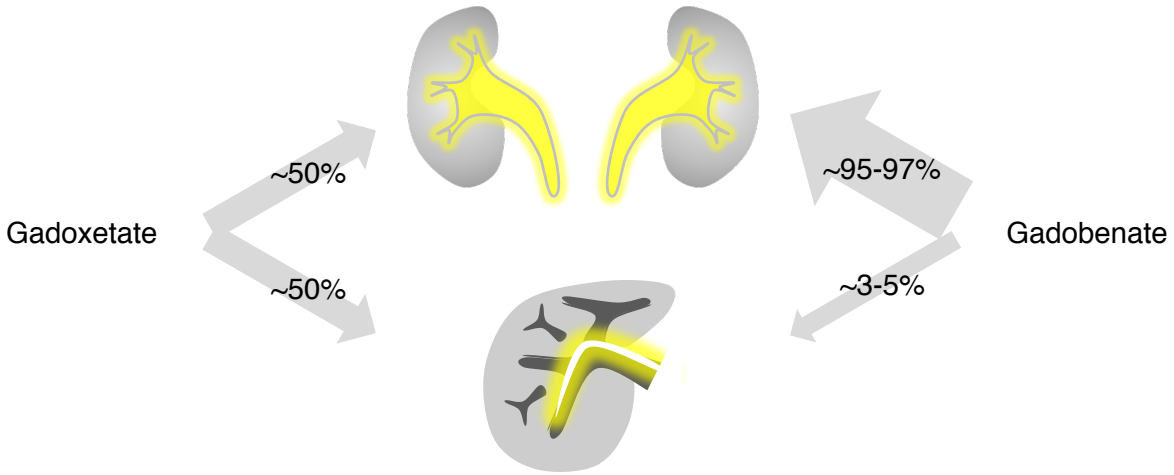
Overview – Hepatobiliary Agents

Hepatobiliary agents (HBAs) distribute initially in the extracellular space and are then taken up by hepatocytes and excreted into the biliary system.

There are two gadolinium based HBAs:

- Gadoxetate disodium, which has high (~50%) and rapid hepatobiliary uptake and excretion.
- Gadobenate dimeglumine, which has modest (~3-5%) and slow hepatobiliary uptake and excretion.

HBAs have dual elimination, they are excreted both by the kidneys via glomerular filtration AND by the liver via the hepatobiliary route.



For gadobenate dimeglumine:

- The amount and rate of hepatobiliary excretion is too small and slow to noticeably affect the clearance of contrast from the extracellular space.
- Thus, enhancement of blood vessels and of lesions with large blood spaces (e.g., hemangiomas) or interstitial spaces (e.g., fibrotic lesions) tends to decline at a similar rate as with ECAs.

For gadoxetate disodium:

- This dual elimination results in rapid clearance from the extracellular space, including the blood and interstitium.
- Thus, enhancement of blood vessels and of lesions with large extracellular volume—large blood spaces (e.g., hemangiomas) or interstitial spaces (e.g., fibrotic lesions)---decreases rapidly compared to ECAs.

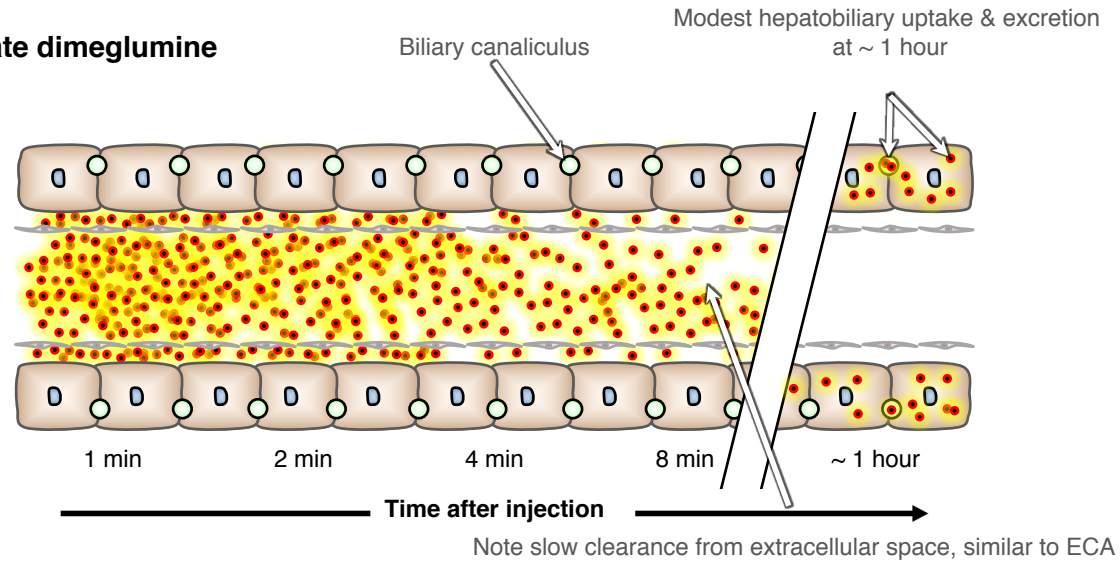
Overview – Hepatobiliary Agents

HBAs may occupy one of four possible spaces, depending on agent and time after injection:

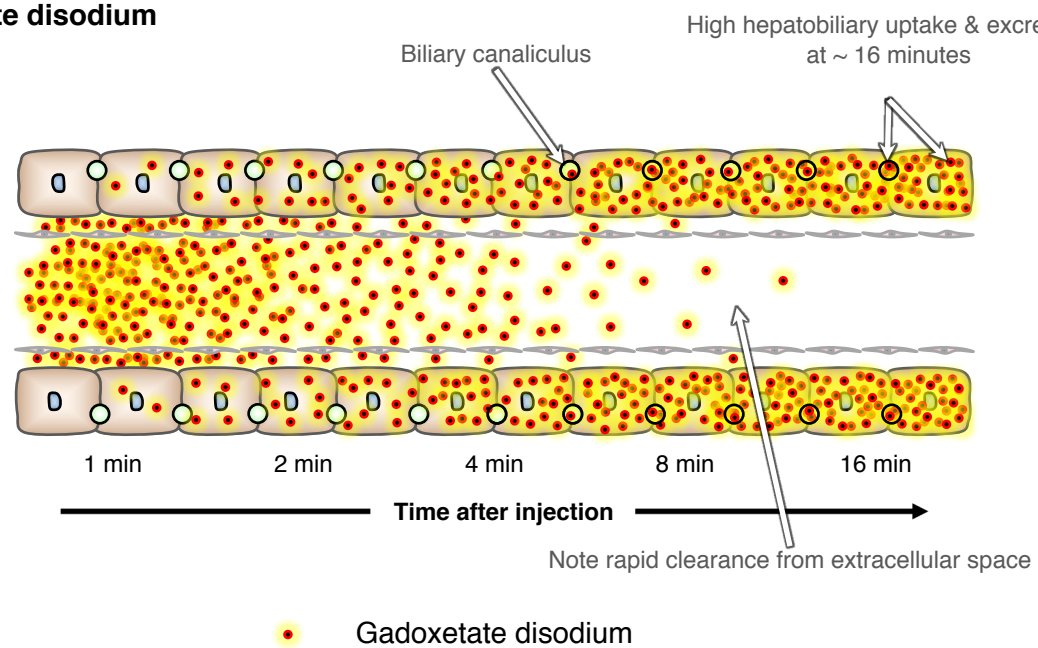
- The vascular space
- The interstitial space
- The hepatocellular space
- The biliary space

The time-dependent distribution of these HBAs in the four spaces is illustrated below:

Gadobenate dimeglumine



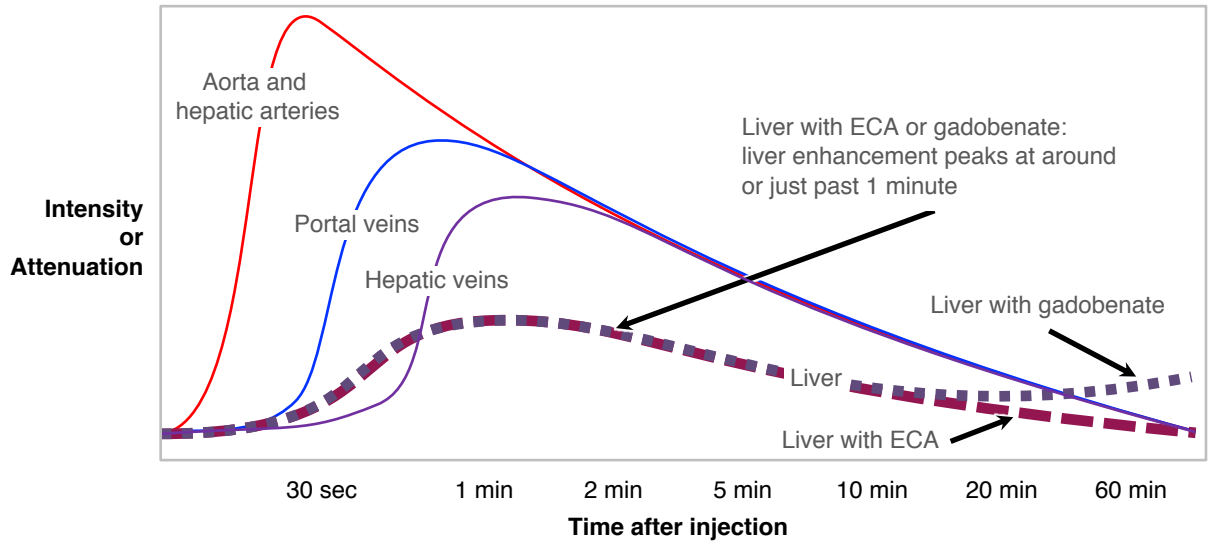
Gadoxetate disodium



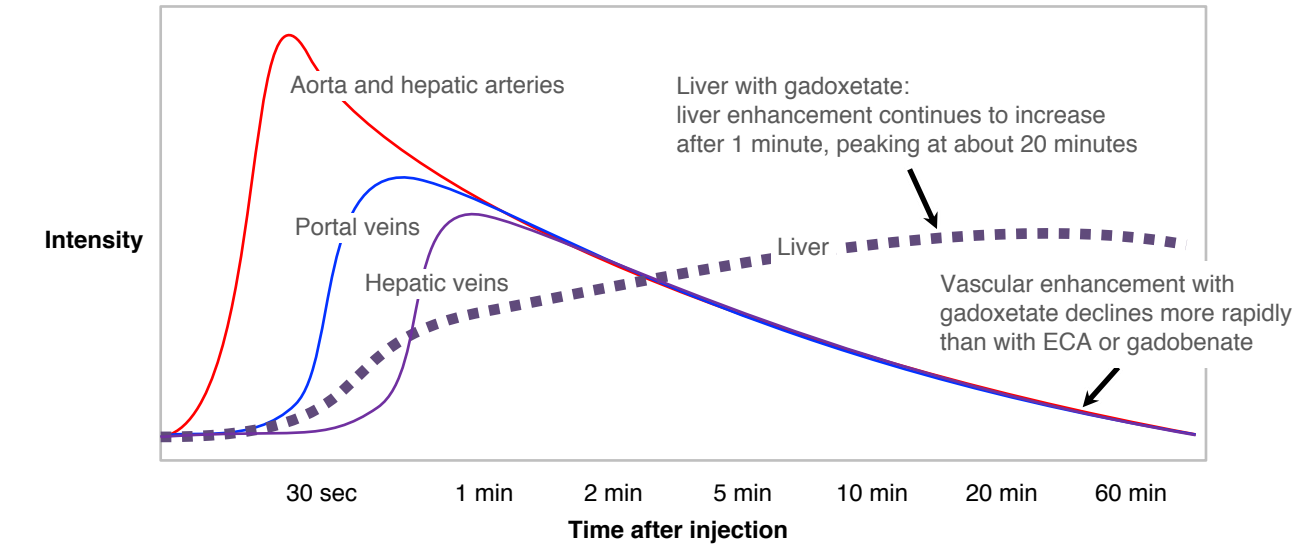
Overview – Kinetics and Temporal Enhancement

Temporal enhancement characteristics are illustrated in the idealized time-intensity curves below

ECAs and gadobenate dimeglumine have similar kinetic properties and produce similar temporal enhancement characteristics during the first few minutes after injection. For both, vascular enhancement declines gradually. Due to hepatobiliary uptake, gadobenate dimeglumine causes substantially greater liver enhancement than ECAs by 1 hour.



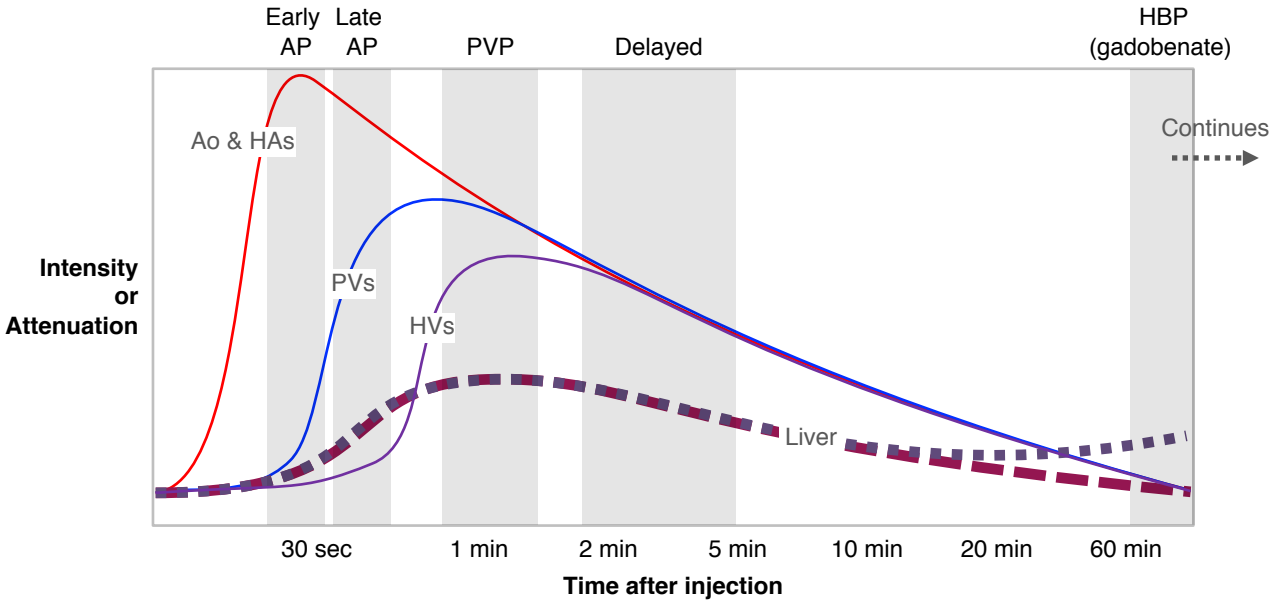
Gadoxetate disodium has different kinetic properties and produces different temporal enhancement characteristics than gadobenate dimeglumine or ECAs**.** Hepatocyte uptake begins during the first pass, becomes noticeable by about 1-2 minutes, peaks by about 20 minutes, and persists for hours. Vascular enhancement declines more rapidly due to dual elimination.



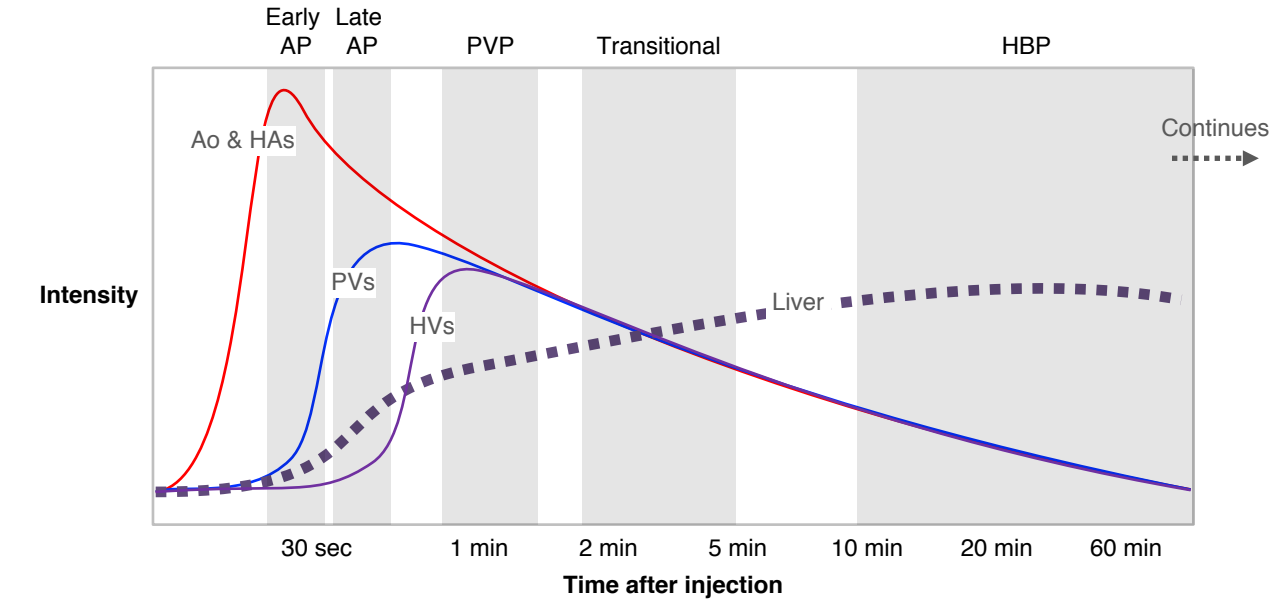
Overview – LI-RADS® CT/MRI Phases

Different tissues and structures reach peak enhancement at different times. This allows the acquisition of images during different "phases". The phases represent a continuum with gradual change overs, but illustrated below as discrete time ranges for simplicity and clinical utility.

Contrast phases with ECAs or gadobenate



Contrast phases with gadoxetate



Overview – LI-RADS® CT/MRI Phases

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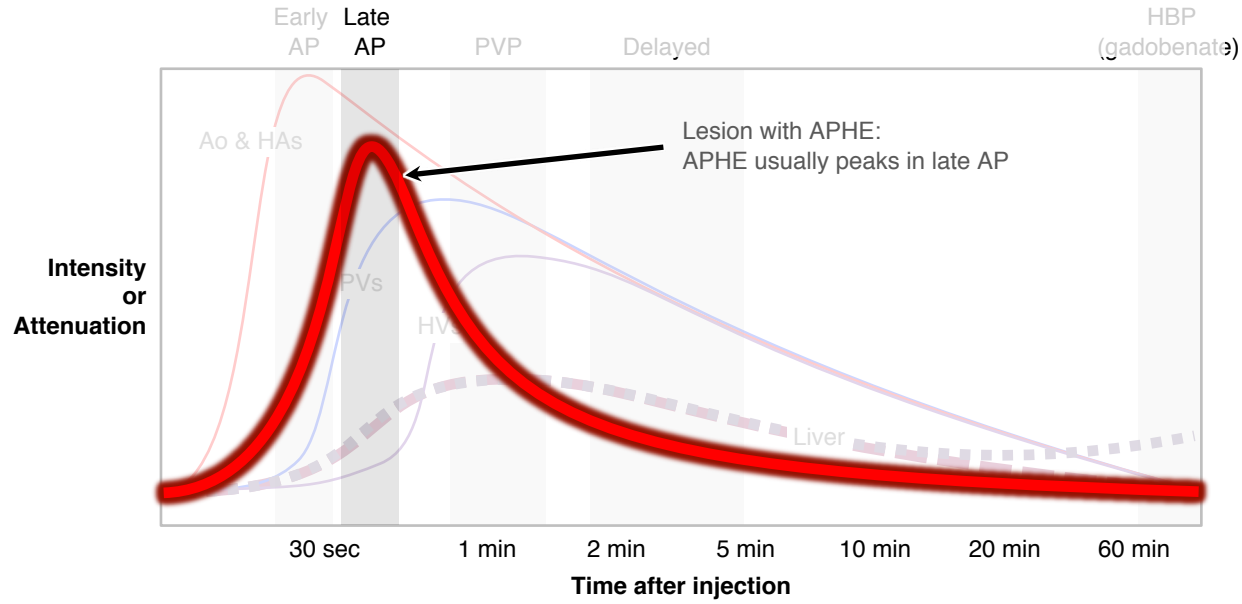
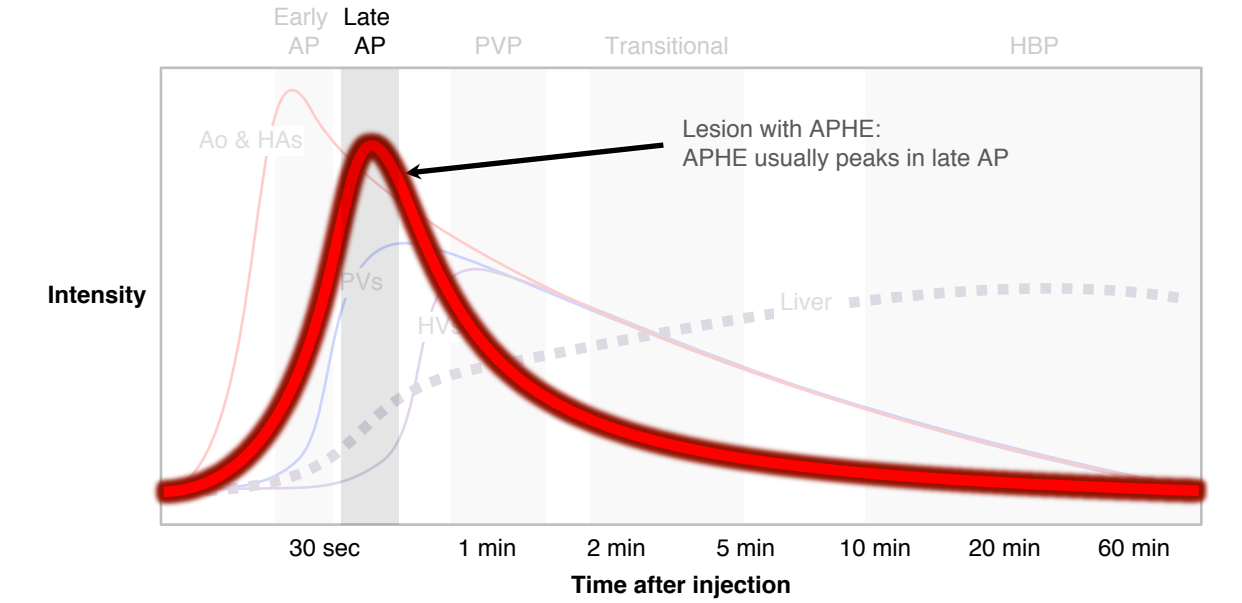


Contrast phases with gadoxetate



Overview – LI-RADS® CT/MRI Phases

Arterial phase (AP)

In LI-RADS, the arterial phase refers to the hepatic arterial phase unless otherwise specified. The arterial phase is a postcontrast time range with the following characteristics:

- Hepatic artery and branches are fully enhanced.
- Hepatic veins not yet enhanced by antegrade flow.

Early AP

Late AP

Two subtypes:

- Early AP: Subtype of AP in which portal vein is not yet enhanced.
- Late AP: Subtype of AP in which portal vein is enhanced.

Late AP is strongly preferred for HCC diagnosis and staging, because the degree of enhancement in HCC usually is higher in the late than in the early AP. Some HCCs may show hyperenhancement only in the late AP.

Extracellular phase (ECP)

Postcontrast phase in which liver enhancement is attributable mainly to the extracellular distribution of a contrast agent. Operationally, this refers to:

- PVP and DP for ECAs or gadobenate dimeglumine.
- PVP only for gadoxetate disodium.

Portal venous phase (PVP)

Postcontrast time range with the following characteristics:

- Portal veins are fully enhanced.
- Hepatic veins are enhanced by antegrade flow.
- Liver parenchyma is at peak enhancement for ECAs.

Delayed phase (DP)

Postcontrast phase acquired with ECAs or gadobenate after the portal venous phase and with the following characteristics:

- Portal and hepatic veins are enhanced but less than in PVP.
- Liver parenchyma is enhanced but usually less than in PVP.

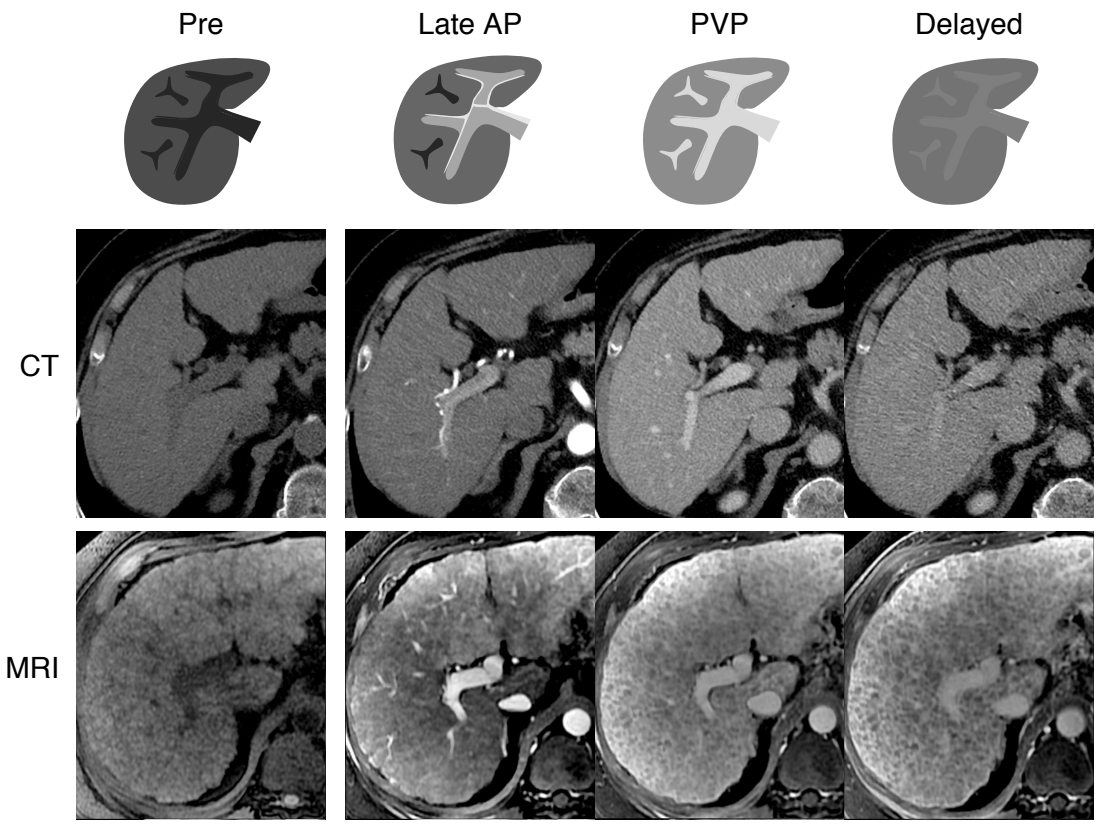
Typically acquired 2 to 5 minutes after injection.

Overview – LI-RADS® CT/MRI Phases

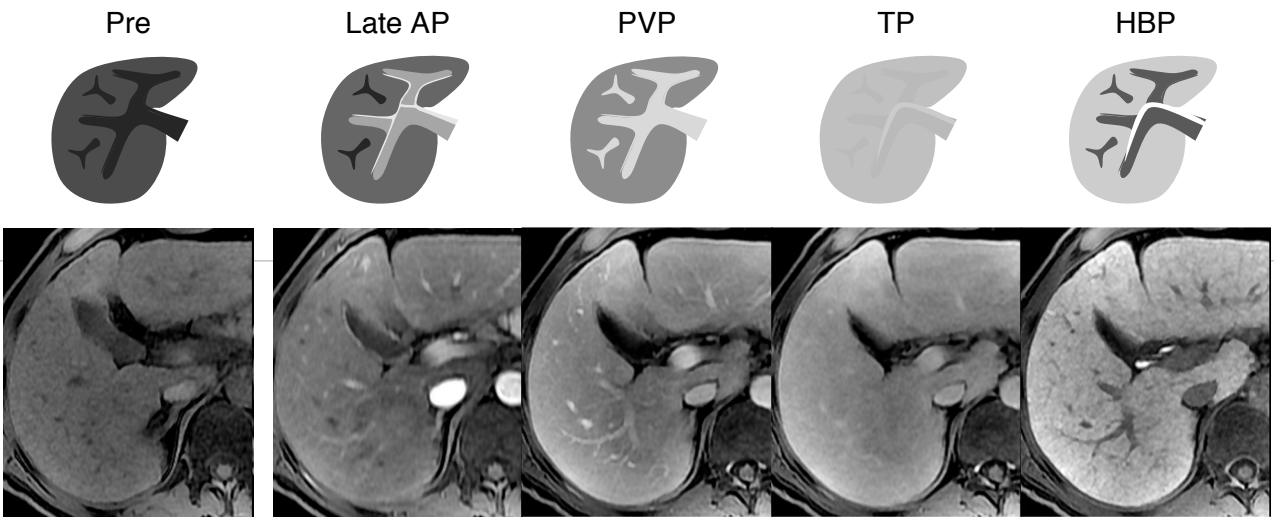
Transitional phase (TP) 	Postcontrast phase(s) acquired with gadoxetate disodium after the PVP, before the hepatobiliary phase, and with the following characteristics: • Liver vessels and hepatic parenchyma are of similar signal intensity. • Both the intracellular and extracellular pools of contrast contribute substantially to parenchymal enhancement. Typically acquired 2 to 5 minutes after injection of gadoxetate disodium. Timing would vary and typically not obtained with gadobenate.
Hepatobiliary phase (HBP) 	Postcontrast phase with HBA with the following characteristics: • Liver parenchyma is hyperintense to hepatic blood vessels. • There may be excretion of contrast into biliary system. Typically acquired about 20 minutes after injection for gadoxetate disodium. If obtained with gadobenate dimeglumine, a delay of 1-3 hours is needed. HBP is suboptimal if liver is not more intense than hepatic blood vessels.

Overview – LI-RADS® CT/MRI Phases

CT or MRI with ECA and MRI with gadobenate dimeglumine



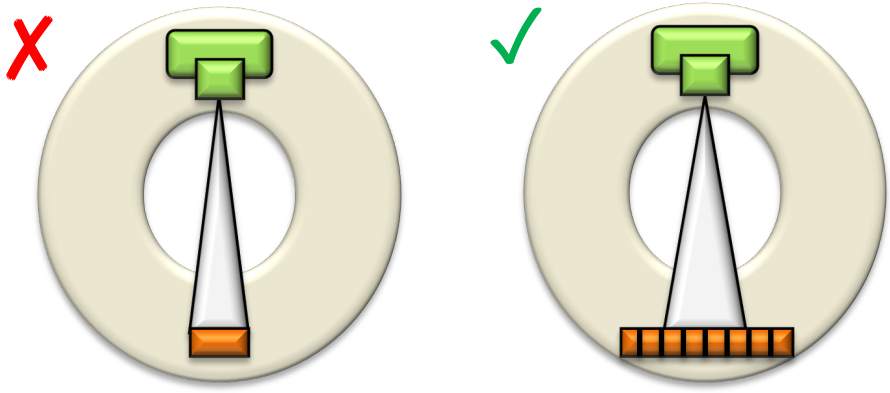
MRI with gadoxetate disodium



CT Scanner Configuration

Required CT Scanner Configuration

LI-RADS requires use of multidetector CT scanners to enable accurate HCC diagnosis and staging. Single-slice CT cannot be used for LI-RADS diagnosis and staging.



Single-slice CT | Multidetector CT

Rationale

Rapid acquisitions are required to capture multiphase images.

Single-slice CT is adequate for portal venous phase imaging but, due to slow scan speed and long acquisition time, has limited ability to scan the liver in multiple phases as required by LI-RADS.

Multidetector CT offers several advantages over single slice CT:

- Reduced gantry rotation time
- Reduced scan duration
- Ability to obtain thinner sections resulting in higher z-axis spatial resolution.

Reduced scan duration enables whole-liver coverage during a short, comfortable breath hold; volumetric acquisitions can be repeated to enable multiphase imaging. Reduced scan duration also decreases motion artifact, particularly in patients with ascites.

Thinner, submillimeter sections diminish partial volume averaging artifacts, which improves sensitivity for small lesions, and allows multiplanar reformation.

Evidence

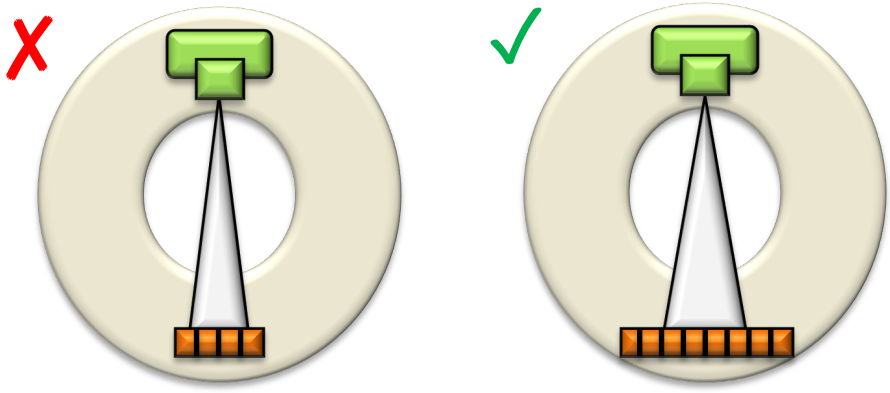
Evidence is indirect, relying on historical data.

- Studies have shown that single-slice CT has low sensitivity for detecting HCC, especially for lesions < 2 cm.
- The advent of multi-detector technology has improved tumor detection rates.

CT Scanner Detector Rows

Minimum number of detector rows

LI-RADS requires a minimum of 8 detector rows. Scanners with 4 or fewer rows cannot be used for LI-RADS diagnosis and staging.



≤ 4-detector row CT

≥ 8-detector row CT

Rationale

Thin slices are required for adequate sensitivity for detecting observations and characterizing major features. As summarized below, 8-row multidetector CT has higher per-lesion sensitivity for HCC than 4-row multidetector HCC.

Additionally, increasing the number of rows from 4 to 8 to 16 to 64 or more allows whole-liver coverage with progressively thinner sections along the z-axis, facilitating generation of isotropic data with sub-millimeter spatial resolution. Isotropic data allow multiplanar reformations in any plane (axial, coronal, sagittal, or arbitrary). In general, the minimum number of rows for acquiring isotropic data is 16, although 8-row multidetector CT can produce high-quality multiplanar reformations.

Evidence

4-row multidetector CT has a reported sensitivity of 73% for detecting HCC overall.

8-row multi-detector CT has a reported sensitivity of 87% for detecting HCC overall.

Additionally, 8-row multidetector CT has a positive predictive value of 96% for detecting HCC in patients with explant pathology reference standard.

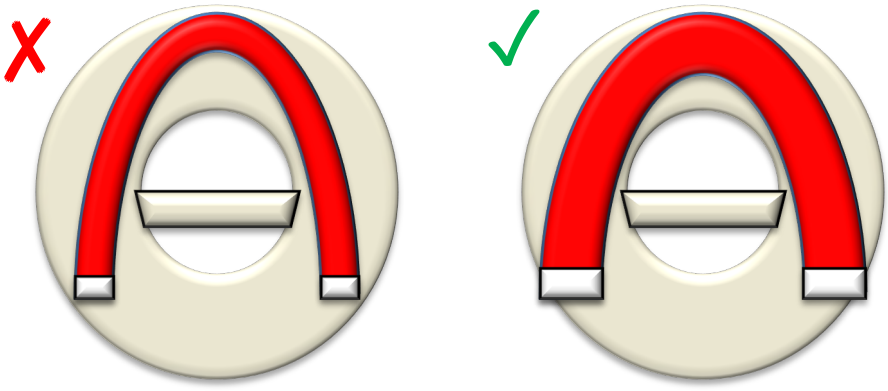
The PPV for 4-row MDCT for HCC with explant pathology is 84.7%.

No studies have compared per-lesion sensitivity of 64-row or 16-row multidetector CT vs. 8-row multidetector CT for detecting HCC.

MR Scanner Field Strength

Required MR Scanner Field Strength

LI-RADS requires use of MR scanners with field strength ≥ 1.5T to enable accurate HCC diagnosis and staging. Scanners with field strength ≤ 1.0T cannot be used for LI-RADS diagnosis and staging.



≤ 1.0 Tesla ≥ 1.5 Tesla

Rationale

MRI of the liver for diagnosis and staging of HCC is typically performed on higher field strength scanners (1.5 or 3 Tesla), which is considered an acceptable minimal standard of care.

Such scanners provide

- Adequate temporal resolution for multiphase imaging AND
- Sufficient spatial and contrast resolution for evaluation of small hepatic lesions.

Generally, liver MRI performed at lower field strengths (≤ 1.0 Tesla) has lower signal-to-noise ratio and inferior image quality.

Evidence

The recommendation for 1.5 or 3 Tesla over ≤ 1 Tesla scanners reflects widespread clinical practice patterns and is based on the universal adoption of 1.5 and 3 Tesla scanners as standard of care for liver imaging.

There are no comparative studies on the diagnostic performance of ≤ 1.0 Tesla vs. ≥ 1.5 Tesla scanners for HCC diagnosis.

The accuracy for diagnosis and staging of HCC is comparable at 1.5 Tesla and 3 Tesla, although 3 Tesla provides higher lesion-to-liver contrast on dynamic contrast-enhanced images.

MR Coil Type

Required Coil Type

LI-RADS requires use of multichannel, phased array coils. If available, a torso coil should be used in most cases. A cardiac coil can be used if a torso coil in not available. Scans acquired with the built-in body coil alone cannot be used for LI-RADS diagnosis and staging.

Rationale

Phased array coils have multiple coil elements designed for volumetric imaging.

Compared to body coils, multichannel phased array coils

- provide higher signal-to-noise ratio and spatial resolution at similar field of view.
- provide better image quality and higher contrast-to-noise ratio, while achieving faster acquisition time, for detecting liver lesions at 1.5 Tesla.

Phased array coils with specific coil element configurations also permit parallel imaging, which can reduce scan time and improve temporal resolution.

In general, coils with more receiver channels enable higher acceleration factors for parallel imaging and provide improved signal-to-noise ratio (SNR). Most state-of-the art MRI torso phased array coils have at least 8 channels, with some having 32 or more channels.

Evidence

The recommendation for using multichannel, phased array coils reflects widespread clinical practice patterns and is based on the universal adoption of such coils as standard of care for liver imaging.

There are no comparative studies on the diagnostic performance of MRI using the body coil versus using a torso phased array coil for HCC diagnosis, but due to the many advantages of multichannel phased array coils as well as their widespread acceptance as standard of care, it is doubtful that such a study will be performed.

Contrast Media Considerations - CT

Technical Suggestion

For CT, LI-RADS suggests use of iodinated contrast medium with:

- Concentration: 300mgI/mL or higher
- Dose: 1.5-2mL/kg body weight
- Contrast injection rate: 3mL/sec or higher

LI-RADS also suggests a saline chaser bolus (30-40 mL) at the same injection rate to follow the contrast bolus. The saline chaser pushes residual contrast in the injection tubing and peripheral veins.

Rationale/Evidence

Important factors that impact image quality: concentration, dose and injection rate of iodinated contrast as well as use of a saline chaser.

Arterial enhancement and detection of APHE depend mainly on injection rate.

Hepatic parenchymal enhancement depends mainly on total iodine dose.

Concentration: Iodinated contrast medium concentrations range widely: 240-400 mgI/mL. Concentrations ≥ 300 mgI/mL yield better HCC detection and image quality.

Patient co-morbidities decrease liver perfusion. Patients with the following conditions may benefit from higher concentrations: reduced cardiac output, obesity, advanced cirrhosis, portal vein thrombosis.. In cirrhosis, higher iodine concentration improves lesion to liver contrast and achieves higher portal venous phase hepatic parenchymal attenuation.

Dose: Weight-based dosing is suggested. Larger patients with larger blood volume may have more dilution of contrast material and lower target organ enhancement than smaller patients.

Optimal dose for liver imaging is 1.5-2 mL/kg body weight. This is equivalent to about 525-600 mgI/kg:

- 350 mgI/mL * 1.5 mL/kg = 525 mgI/Kg
- 300 mgI/mL * 2 mL/kg = 600 mgI/kg

This dose yields an absolute parenchymal enhancement of $\geq$ 50 HU.

Injection rate: Injection rates > 3 mL/s improve sensitivity for detection of hypervascular HCC, especially for small lesions.

Contrast Media Considerations - MRI

Types of MR contrast agents

Two different types of Gd-based MR contrast agents can be used for LI-RADS categorization:

- Extracellular contrast agents (ECAs)
- Hepatobiliary contrast agents (HBAs)

Both types of agents have advantages and disadvantages, and both permit noninvasive diagnosis of HCC with high specificity if stringent criteria are applied (i.e., LR-5 criteria).

HBAs, like ECA, yield similar enhancement characteristics on arterial and portal venous phases, but also provide hepatobiliary phase (HBP) information. This combination of information can improve detection of HCC..

LI-RADS does not recommend one type of agent over another, recognizing that the optimal agent selection depends on patient, radiologist, institutional practice and other factors.

Types of MR HBAs

There are two clinically available HBAs:

- Gadoxetate disodium
- Gadobenate dimeglumine

Both agents have relatively high relaxivity compared to ECAs, which potentially permits detection of smaller lesions.

Both agents are taken up and excreted by hepatocytes, but they differ in the degree of hepatobiliary excretion.

- Gadoxetate disodium ~ 50%
- Gadobenate dimeglumine ~ 3-5%

Please see *Chapter 13* for more information on gadoxetate and gadobenate.

Contrast agent dose and injection rate

Dose: please see package insert for manufacturer recommended dose

Contrast injection rate: 1-2 mL/sec

LI-RADS also suggests a saline chaser bolus (30-40 mL) at same injection rate to follow the contrast bolus. The saline chaser pushes residual contrast in the injection tubing and peripheral veins.

CT Protocol

Minimum required phases with CT

- Arterial phase (late arterial phase strongly preferred)
- Portal venous phase
- Delayed phase (typically acquired 2 to 5 minutes after injection)

Precontrast imaging is suggested if patient has had locoregional treatment; it is optional otherwise.

Rationale for selected phases

The required phases are selected to

- accentuate lesion to background enhancement and
- permit characterization of LI-RADS major features as well as LR-M, LR-TIV, and ancillary features.

Precontrast imaging is optional for CT in treatment-naïve patients, because it adds radiation exposure with low incremental benefit.

Precontrast imaging is suggested in treated patients to differentiate tumor enhancement versus intrinsic posttreatment hyperdensity from blood, proteinaceous material, or iodized oil.

AP and PVP are required for characterization of APHE, WO and enhancing “capsule”.

DP improves HCC detection and characterization, particularly for small lesions, and is more sensitive for detection of WO and enhancing “capsule” than PVP.

CT Protocol

Technical considerations

All multiphase acquisitions	Slice thickness	≤ 5 mm
Timing of multiphase sequences	Arterial phase	Bolus tracking or fixed time delay is suggested Bolus tracking: • Aortic triggering is performed at L1 level, celiac axis, or diaphragmatic hiatus. • After threshold aortic enhancement of 100-150 HU is reached, a scan delay of 15-30 s is suggested for late AP acquisition. Fixed time delay: • 35-45 s after starting injection with rate of 3-5 mL/s
	Portal venous phase	60-75 s after starting injection at 3-5 mL/s, regardless of how the arterial phase is timed
	Delayed phase	2-5 min
Multiplanar reformats	Multiplanar reformats are recommended in the coronal and sagittal planes for arterial and portal venous phase images. Multiplanar reformats are optional for delayed phase images	

MRI Protocol

Minimum required phases with MRI

For MRI with all contrast agents:

- Precontrast imaging
- Arterial phase (late arterial phase strongly preferred)
- Portal venous phase

For MRI with ECA or gadobenate

- Delayed phase (typically acquired 2 to 5 minutes after injection)

For MRI with gadoxetate

- Transitional phase (TP) (typically acquired 2 to 5 minutes after injection)
- Hepatobiliary phase (HBP) (typically acquired 20 minutes after injection)

Other required sequences

- T1-weighted out-of-phase (OP) and in-phase (IP) imaging (precontrast)
- T2-weighted imaging (pre or postcontrast) (fat suppression is optional)

Optional phases/sequences

- Diffusion-weighted imaging (DWI) (pre or postcontrast)
- HBP with gadobenate (typically acquired 1-3 hours after injection)

Rationale for required phases

The rationale for the required phases is similar to CT (see *page 12-19*) with the following differences:

- Precontrast images establish the intrinsic T1 intensity of observations, provide a baseline against which contrast enhancement can be identified, and allow for subtraction imaging. These are required since there is no additional exposure to ionizing radiation.

- TP aids in lesion detection and diagnostic confidence, as HCCs, LGDN and HGDN often are hypointense in TP.

- HBP imaging improves sensitivity and specificity for HCC diagnosis (see *Chapter 13*).

MRI Protocol

Rationale for other required sequences

T1-weighted OP and IP imaging (precontrast) allows for the detection of intralesional fat/iron and fat and iron sparing, which are LI-RADS ancillary features (see *Chapter 16*).

T2-weighted imaging is necessary for characterization of some ancillary features (see *Chapter 16*); provides information about the presence of fluid, fibrosis and iron; allows distinction between solid and nonsolid lesions; can increase diagnostic confidence.

Rationale for optional phases/sequences

DWI improves detection of hepatic observations, and is necessary for characterization of some LR-M and ancillary features (see *Chapter 16*). DWI is optional, not required, due to its inconsistent image quality. DWI is prone to artifact/image degradation.

HBP with gadobenate is optional due to the slow and modest uptake of this agent, which requires a long (~1-3 hour) delay and makes HBP imaging impractical.

Technical considerations

All multiphase sequences	Weighting	T1 weighted
	Acquisition type	3D is strongly recommended
	Fat suppression	Strongly recommended
	Slice thickness	≤ 5 mm
	Comment	Postcontrast acquisition parameters should match precontrast parameters to facilitate subtraction. Optionally, the flip angle can be increased in the HBP to enhance T1 weighting.
Timing of multiphase sequences	Arterial phase	• Bolus tracking is recommended. • Multiarterial acquisition can have a fixed delay.
	Portal venous phase	60-80 s after the start of injection at 3-5 mL/s
	Delayed phase	2-5 min
	Transitional phase	2-5 min
	Hepatobiliary phase	~ 20 min (with gadoxetate) ~1-3 hrs (with gadobenate)

MRI Protocol

Technical considerations (Cont'd)

T2-weighted imaging	Acquisition type	• 2D single shot (SSFSE/HASTE) **OR** • 2D fast spin echo techniques (FSE/TSE)
	Fat suppression	Optional
	Slice thickness	≤ 8 mm, slice gap, ≤ 2 mm
	Other	Acquisition in coronal and axial planes is recommended.
T1-weighted out-of-phase (OP) and in-phase (IP) imaging	Acquisition type	• Dual-phase acquisition is strongly recommended. • OP should be acquired as the first echo. • Both 2D and 3D acquisitions are acceptable. • IP and OP images can be generated as part of Dixon acquisition.
	Fat suppression	None
	Slice thickness	• If 2D: ≤ 8 mm, slice gap ≤ 2 mm • If 3D: ≤ 6 mm
Diffusion-weighted imaging	Acquisition type	• Single shot echoplanar imaging (SS-EPI) with ≥ 2 b-values (including b=0-50 and b=400-1000 s/mm^2. • Can be acquired using breath-hold, free-breathing, respiratory-gated techniques or multiple signal averages.
	Fat suppression	N/A
	Slice thickness	≤ 8 mm slice gap, ≤ 2 mm
	Other	• Higher b-values can improve specificity for HCC, but have lower SNR. • Free breathing sequences allow for more b-values, higher SNR and thinner sections vs breath-hold, but are longer to acquire and more artifact prone. • Parallel imaging is recommended to reduce artifacts.

Subtraction Imaging

Definition

Subtraction imaging refers to post processed images generated from subtraction of precontrast from postcontrast images.

Technical Recommendation

Subtraction imaging is suggested for liver MRI to characterize APHE and/or “washout” appearance of intrinsically T1 hyperintense observations.

- Subtracting the precontrast from the arterial phase T1-weighted images can be used to characterize APHE (see *Chapter 16, page 26*)
- Subtracting the precontrast from the portal venous or, if an ECA or gadobenate is used, delayed phase T1-weighted images can be used to characterize washout appearance (see *Chapter 16, page 104*)

Radiologists and institutions can determine whether to generate subtractions routinely or only in select cases when needed.

Subtraction images can usually be obtained at the scanner console by automatic subtraction of the precontrast T1-weighted images from the postcontrast T1-weighted images.

For subtractions to be valid, precontrast and postcontrast phases must be acquired with identical technique – including the same sequence and image-weighting parameters (e.g., TR, TE, flip angle, and calibration settings) and be properly registered.

Coregistration can be facilitated by patient education prior to scanning and acquiring breathhold images at relaxed end expiration.

Rationale for suggesting subtraction imaging:

- Subtraction imaging can enable characterization of APHE and washout appearance for intrinsically T1 hyperintense lesions.
- Subtraction improves accuracy and reader confidence for assessment of tumor necrosis following locoregional therapies by improving detection of APHE related to residual/recurrent tumor.

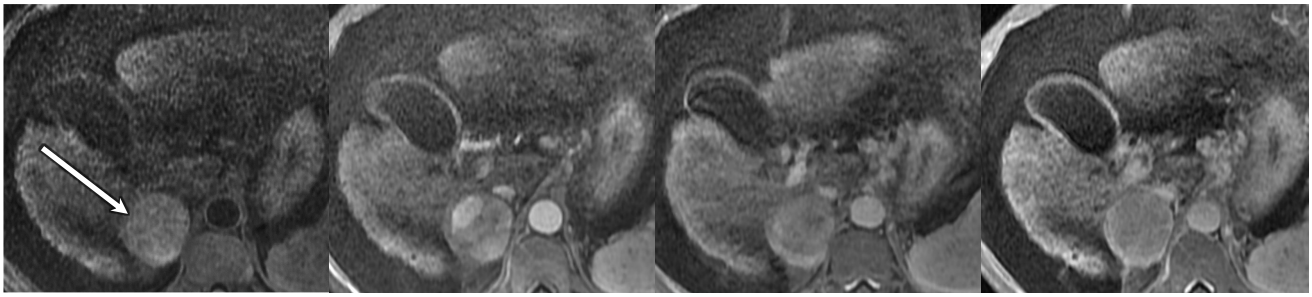
Rationale for not requiring subtraction imaging:

- They cannot be automatically produced on all scanners, require additional workflow steps, and add to the number of images being transferred and stored.
- Misregistration between unenhanced and enhanced images can be a source of artifact and result in false-positive characterization, particularly for observations at the periphery or dome of liver.

Subtraction Imaging

- *Example: Subtractions*

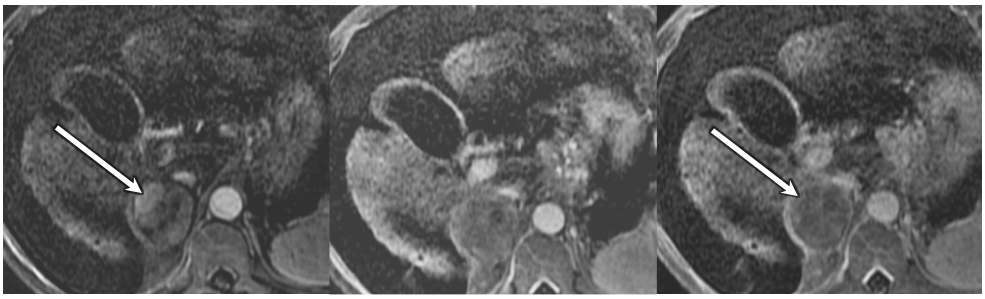
Pre | AP | PVP | DP



High signal on pre

Assessment of APHE and WO is confounded by intrisically high T1 signal

Sub AP | Sub PVP | Sub DP



Subtractions confirm presence of APHE and DP WO

Diffusion Weighted Imaging

Definition

Diffusion-weighted imaging refers to images in which contrast is generated mainly or largely by differences in diffusivity between tissues.

Since the echo times required to generate diffusion-weighted images are generally intermediate to long (i.e., ≥ 40 ms), the images are also T2 weighted.

Technical Recommendation

Diffusion-weighted imaging is suggested for liver MRI to

- improve sensitivity for HCC by detecting lesions that may be difficult to see on other sequences
- increase diagnostic confidence, and
- permit characterization of
  - one ancillary feature favoring malignancy (diffusion restriction) and
  - two LR-M features (targetoid appearance at DWI, marked diffusion restriction).

DWI is highly sensitive to artifacts (susceptibility, motion artifacts, etc.). Artifacts can be greatest in the left lobe (cardiac and diaphragm motion, air in the stomach, upper and lower GI tract). Techniques to lessen artifacts include (but are not limited to): respiratory gating, parallel imaging, using relatively low imaging matrix.

DWI quality is similar pre- and post-contrast. Consider acquiring DWI post contrast if that would reduce overall scanner time and/or reduce the risk of patient fatigue during dynamic contrast-enhanced imaging.

Rationale for suggesting diffusion weighted imaging:

- Diffusion-weighted imaging can improve sensitivity for HCC and reader confidence, and it can permit characterization of some ancillary and LR-M features.

Rationale for not requiring diffusion-weighted imaging:

- High-quality diffusion-weighted imaging cannot be achieved consistently on all MR scanners.

Advanced and Emerging Techniques

Dual energy/multispectral imaging

Insufficient evidence for LI-RADS to recommend for or against the use of dual energy/multispectral imaging.

Multiarterial phase MRI

Insufficient evidence for LI-RADS to recommend for or against the use of multiarterial phase imaging

Susceptibility-weighted MRI

Insufficient evidence for LI-RADS to recommend for or against the use of susceptibility-weighted imaging.

Quantitative imaging techniques

Insufficient evidence for LI-RADS to recommend for or against the use of quantitative imaging techniques/biomarkers for LI-RADS categorization.

Examples of these techniques/biomarkers include:

- Confounder-corrected chemical shift encoded MRI to quantify proton density frat fraction (PDFF) – a measure of tissue lipid content
- Multi-echo or confounder-corrected chemical shift encoded MRI to quantify R2* – a marker of iron content
- Magnetic resonance elastography to quantify stiffness – a marker of fibrosis
- Other:
  - Perfusion analysis to quantify perfusion parameters, texture analysist to quantify texture features, DWI volumetric analysis to quantify volumetric ADC

Technical Recommendations for CT at a Glance

Scanner configuration	Multidetector row scanner
Detector rows	≥ 8 detector rows
Multiplanar reformations	Suggested
Slice thickness (for axial reconstructions and, if obtained, multiplanar reformations)	≤ 5 mm required (2.5 – 3 mm suggested for multiplanar reformations)
Precontrast imaging	• Suggested for patients treated with locoregional therapy • Optional otherwise
Contrast-enhanced phases	The following are the minimum required phases for both treatment-naïve and treated patients: • Arterial phase • Late arterial phase strongly preferred • Portal venous phase • Delayed phase (2-5 minutes after initial injection of contrast)
Timing of arterial phase	Bolus tracking or fixed-time delay is suggested
Contrast considerations	• ≥ 300mgI/mL for a dose of 1.5-2.5 mL/kg body weight • Injection rate of ≥ 3 mL/sec • Saline chaser bolus (30-40 mL) with same injection rate • Power injector

Technical Recommendations for MRI at a Glance

MR Scanner		1.5 or 3T
Coil type		Phased array multichannel torso coil

Required imaging	Multiphase	Multiphase 3D T1WI is required with the following phases:
		• Precontrast
		• Arterial phase
		  • Late arterial phase strongly preferred
		  • Multiarterial phase imaging is optional if available
		• Portal venous phase
		• Delayed phase (2-5 minutes) if using ECA or gadobenate
		• Transitional phase (2-5 minutes) if using gadoxetate
		• Hepatobiliary phase (~20 minutes) if using gadoxetate
		
		Fat suppression is suggested

	Other	• Unenhanced T1-weighted OP and IP imaging • T2-weighted imaging (fat suppression optional)
Suggested imaging		• DWI • Multiplanar acquisition(s)
Optional imaging		• Hepatobiliary phase (~1-3 hours) if using gadobenate • Quantitative imaging techniques, if available, are optional
Timing of arterial phase		Bolus tracking is suggested
Slice thickness		See pages corresponding to each phase or sequence
Contrast considerations		• ECA or gadobenate or gadoxetate • Weight-adjusted dose • Injection rate of 1-2 mL/sec • Saline chaser bolus (30-40 mL) with same injection rate • Power injector

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